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FORESTS AND THEIR EFFECT ON CLIMATE, WATER SUPPLY AND SOIL.

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[Presented by title at meeting of the Society, March 13, 1913.]

THE theory that forests on the watershed of a stream act as a substantial conserver of precipitation has been accepted by the great mass of people as an established fact. It is a plausible theory and has been so oft-repeated that those who have given the subject only casual thought or superficial study accept it without further question.

The truth of the matter is, however, that this theory is neither established nor admitted by many whose opinions on the subject we are obliged to respect. There is no evidence in the world to-day that will either absolutely establish or absolutely refute the theory. Because of this fact it is necessary, in order to reach a rational conclusion on the subject, to resort to inductive reasoning and then to draw whatever conclusions are warranted by such data as we have.

I shall first treat the subject of precipitation, run-off, erosion, etc., and the relation of forests thereto in a general way. Next, I shall present whatever data I have been able to gather on the subject.

RELATION OF RUN-OFF TO PRECIPITATION.

When water is precipitated in the form of rain, a portion of it runs from the surface directly into the water-courses of the region, and a second portion percolates into the soil and

underlying rocks and appears lower down in the stream channels in the form of springs or seepage water. Those two portions together constitute the run-off from the watershed. A third portion sinks too deep into the ground to appear as run-off. A fourth portion is evaporated directly from the water surfaces, moist soil and wet vegetation on the area. A fifth portion is transpired by plant growth, i. e., given off as vapor from plant leaves and used in the body of the plant itself. A sixth portion remains stored in lakes or in the interstices of the soil and rocks comprising the area. If precipitated in the form of snow, the water is not disposed of in accordance with these several processes until melting occurs.

The water that falls on an area disappears by any or all of the six routes above outlined, and the proportion that disappears in each depends upon the conductivity of each route, so to speak.

The amount of run-off depends upon the following principal factors:

1. The porosity of soil and underlying strata. On this largely depends the division of water between surface flow and shallow percolation.

2. The intensity and nature of precipitation. Gentle showers for several days may produce very little run-off, while half the amount falling in a few hours would produce a flood. A snowfall, of course, produces no run-off until melting occurs; then the water disposes itself in virtually the same manner as if newly precipitated.

3. The condition of the ground prior to precipitation. If frozen or saturated, no infiltration is possible. A snowfall on frozen ground will all appear as run-off when it melts. If the ground was unfrozen, considerable water may percolate into it at the time of melting. Completely saturated ground acts in a similar manner with rainfall.

4. The topography of the area. Steep slopes permit rapid surface flow, while gentle slopes permit greater percolation, other factors being equal.

5. Cultivation. This effects the porosity of the surface soil. Fallow fields are very receptive to percolation.

6. Vegetation. The roots and stems of grasses, brush, trees, etc., mechanically retard, to some extent, the flow of surface water and permit percolation. The principal effect of vegetation, however, is through the medium of evaporation and transpiration.

7. Evaporation and transpiration. The greater the evaporation the less the run-off, other things being equal. The greater the area of lake surface on a watershed, the greater the amount of evaporation. Trees and plants evaporate enormous quantities of water as long as they are wet, and continue to transpire large quantities of water long after evaporation has virtually ceased.

There are others, but these are the principal factors, and they are so related one with another that the effect of one cannot be isolated except under identical conditions regarding every other. The meagerness of data with which to solve problems in which these factors are involved, and the complexity of the problem, are at once apparent. The relation between precipitation and run-off has engaged the attention of engineers for years, yet up to the present time no satisfactory relation has been established between them. All that we can expect to show are general tendencies produced by certain factors. It is impossible to account for all the factors that enter into the problem. No two drainage areas are alike, hence each area is a law unto itself in this respect.

Effect of Forests on Run-off.

In arriving at any rational conclusions as to the effect of forests considered apart from all the other factors, no hard and fast rules can be laid down. The evidence gathered from experimental data and observation is so conflicting that only the more general conclusions can be utilized. Each region must be considered on its own merits, in the light of general knowledge adapted to its own peculiar conditions.

Many beneficial effects of forests are claimed that do not exist at all, and other claims are too intangible to admit of serious consideration. The following are a few claims that will be dimissed with the mere statement of them* and the remark that if they exist at all they are not of sufficient magnitude to be of economic importance:

(A) Extremes of temperature of air as well as of soil are prevented.

(B) The average humidity of the air is increased.

(C) The disposition of precipitation throughout the year is favorably affected.

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* Taken mainly from Bulletin No. 7, Department of Agriculture, Forestry Division, "Forest Influences."

(*D*) By condensing dew, hoar-frost and ice on their branches, trees add to the precipitation.

(*E*) Forests keep the soil underneath granular and porous for the reception of water.

(*F*) Oxygen and ozone production by forests increase the purity of the air.

(*G*) Soil conditions of the forests are unfavorable to the production and existence of pathogenic microbes.

The claims that will seriously engage attention may be briefly summarized as follows:

1. Forests induce greater uniformity of stream flow than would obtain without them.

2. Forests prevent soil erosion.

3. Forests increase precipitation.

The agencies by which forests are said to increase the uniformity of stream flow are:

1. The bed of humus that develops under a forest cover retains a portion of the water that falls during wet periods and delivers it to the streams through the underlying soil in dry periods. Floods are diminished and low stages augmented by the amount of water thus retained.

2. Forest litter, roots, etc., mechanically retard the flow of water over the land surface and discourage the rapid rush of water into the streams. Soil erosion is thus prevented and flood heights diminished.

3. Forest shade retards the melting of snow in the spring and thus the period of run-off is prolonged.

Each of these generally accredited properties of forests will be considered first in general terms, then with such actual data as I have been able to gather on the subjects.

Percolation. — Liberal percolation of water into the underlying soil is a necessary factor for uniformity of stream flow. We may consider the humus and the soil under a forest as two media of different porosity. If the humus is more porous than the soil, percolation into the soil will be favored; but if the soil is more porous than the humus, less water will percolate than if the soil were directly exposed. A saturated stratum is impervious to water, hence in a fine soil the upper layer may become saturated and held in place by capillary action in the overlying humus. In this condition, any additional water simply runs off. The term humus is taken to include all the litter from the surface of the forest floor to the soil underneath it. The upper layers are coarse twigs, leaves, needles,

etc., giving place to rotten wood, leaf- and wood-fibers intermingled, and gradually merging into a fine dustlike mold, and finally into the main soil itself. Percolation is the result of two forces,—gravity acting downward, and capillarity acting upward. Gravitational forces are constant in all soils, while the finer the soil, the greater the force of capillarity. In gravel it is practically negligible, in fine clay it may effectively prevent percolation. If, then, a fine mold overtops a porous soil, less water will percolate than if the porous soil were directly exposed. On a compact soil the mold cannot increase percolation except by arresting the lateral motion of the water and allowing the force of gravity to act longer. In compact soils the amount of percolation is never very great, and the increment due to a humus cover is of the second order of magnitude and can scarcely be of economic importance.

The general claim that the humus gives up its water is directly contrary to physical laws. The forest cover has been likened to a sponge that fills with water which it gradually pays out to the streams. The fallacy of this theory is evident upon reflection. Water does not drain from a saturated sponge except when more water is added. It holds all it receives until saturated. So with the humus (except that the humus is very far from being anything like a sponge); it holds its water until saturated, then water begins to run off and percolate. If the supply is less than sufficient to saturate, the water is evaporated gradually and little or no percolation takes place.

Experiments to determine the amount of rain water percolating through various soils with various covers have been conducted in European countries, but to the present time no absolute conclusions have been reached on the effect of humus. Dr. Ernst Ebermayer, from a long series of experiments in Bavaria, comes to the conclusion that deep humus imbibes almost all percolation and gives up very little water below. He says: " If our earth were covered with a humus soil of one meter in depth, subterranean drainage would be so slim that springs would be scanty and continuous flowing springs absent."

Very elaborate and careful researches by Dr. Otosky on the steppes and forest lands of Russia, by Professor Morasof in the fir forest of Khrienof, and by Professor Henry of the forest school of Nancy, in the Mendon Forest, France, and by other observations in both Europe and American countries, have demonstrated conclusively that the ground water in forests is at a lower elevation than in the open country. This results

from the fact that the trees require large quantities of water for their sustenance and growth. The trees literally "pump" water from the ground and dissipate it by transpiration, and this property has even been put to use in the artificial drainage of marshes. Mr. Lokhtine, in a paper presented to the Tenth International Navigation Congress, held at Milan in 1905, says:

"As a general rule standing on these observations (those of Otosky, Morasof, Henry and others), it seems as though it could be considered as proved that the forest evaporating into the air a large amount of water and withdrawing it from the ground by means of its roots, dries the stratum of the ground into which its roots penetrate, and draws down the level of the subterranean waters. Whence this conclusion, opposed to the former view, that not only does the forest not preserve moisture for the supply of brooks and rivers, but it actually does them harm in this respect. The forest is no longer considered as having more than a certain usefulness in holding back the run-off of surface water. This is the conclusion at which Professor Volny, for example, arrived, and the venerable sylviculture specialist, Mr. Ebermayer, has spoken of it in the same way, although it was on his authority that reliance used to be placed to demonstrate the utility of forests for supplying rivers. He has now changed his opinion and admits that it was incorrect, at least so far as flat countries are concerned. 'Forests,' he says, 'do not increase the quantity of water in springs, but reduce it.'"

Opposed to this eminently scientific view is the general belief that small springs generally dry up following the removal of forests, but on this point the evidence is so conflicting that no conclusions are possible. My own opinion, gathered from the observation and the study of a great mass of literature on the subject, is that a humus cover on soil does not materially affect the amount of percolation one way or the other. On porous soil the humus tends to discourage percolation, while it may increase it slightly on a compact soil; but in either event the increment or decrement for which the humus alone is responsible is of no material value. If this is true, the amount the floods are diminished and low stages augmented is limited to the water-holding capacity of the humus itself. This capacity is very small, and the amount retained from a shower will depend upon its previous condition of saturation. It takes very little rain to saturate a forest litter, and once saturated its power to prevent run-off is exhausted. Moreover, the value of forest litter

in this respect must be measured, not by its absolute capacity but by its capacity in excess of that of naked soil. The results of Dr. Ebermayer's experiments* are illuminating on this point. He found that the capacity of the litter in a spruce forest 120 years old was virtually twice that of the naked soil (similar to that under the litter) *for the first two inches of depth*, but for greater depth the naked soil had slightly greater holding capacity.

The larger openings between sticks and twigs cannot hold a great deal of water. The capacity of humus, therefore, is concentrated in its lower part or in the vegetable mold lying between the soil and this coarser litter. This mold is so light that on steep slopes it does not accumulate to any extent, but is washed into the flatter portions of the area. The total volume and hence the capacity of this layer of water-bearing mold even on an old forested area is utterly insignificant when compared with the volume and water-holding capacity of all the soil and rock formations composing the area. Even in the older forests this mold can never have a volume greater than about 1-10 000 part of the volume of the drainage area, and any increased capacity in the holding power of this slight volume is utterly negligible. Moreover, the needles of conifers and leaves of deciduous trees frequently form a veritable thatch over the litter and humus that allows water to run off without even wetting it. This of course is most marked on sloping ground.

The statement is frequently made that a forest litter keeps the soil underneath granular and makes it more susceptible to percolation. That this is contrary to physical laws is also evident upon reflection. The soil of an area must sustain the weight of the trees and the stress produced by winds. In mature forests from three to five per cent. of the area at the surface of the ground is solid wood. For the first two feet under the surface the quantity of wood is probably six or seven per cent., and all of this soil is compacted into a tight band between the tree roots. Ocular evidence of this is displayed by the masses of earth and bowlders that cling to the roots of upturned trees. Such a mass is frequently ten or twenty times the area of the tree trunk and sometimes resists the erosion of rains and winds for years. Such soil exists under every tree, and it is more than likely that in dense forests 25 to 30 per cent. of the soil area is thus compacted into a solid mass. Such a soil is far from granular and is not conducive to percolation.

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* Bulletin No. 7, "Forest Influences," page 146.

With a given quality of soil the fallow field is the most receptive to percolating water. Meadow lands and pastures are probably second in order, with brush land third, and dense forest fourth.

Evaporation and Transpiration. — These two phenomena in the realm of science are entirely separate and distinct, but for the purposes of studying forest effects they can be considered together.

The water dissipated by evaporation, exhaled by plants, and absorbed by plant growth, represents certain losses that reduce the quantity available for percolation and run-off.

Under forest shade and wind protection, the evaporation from a water surface and from continually wet soil and litter is about one half* that from similar surfaces in the open. Now, the absolute evaporation from water surfaces in the United States varies from 30 to 100 in. and in arid and semi-arid regions is even greater than the annual precipitation. If an annual rainfall of 40 in., say, was uniformly distributed throughout the year (0.11 in. per day) it would practically all evaporate. That it does not is due to the fact that the rain is not uniformly distributed, and the percentage of precipitation that does evaporate is seen to depend almost entirely upon the distribution of rainfall and the climatic influences attending it, while the character of the land surface is of secondary importance. In other words, the amount actually evaporated is governed by the amount of water available for evaporation. This is also true of transpiration. Plants transpire in proportion to the amount of water at their dispcsal. In a coniferous forest, under average conditions of rainfall, the transpiration is equivalent to from five to ten inches† over the area of the forest. If the roots are plentifully supplied with water, trees may transpire several times this amount; or in a drier soil they may transpire only a fraction thereof, and still live.

The action of a forest cover in this regard must be weighed against that of the open field. After a shower falls in the open, evaporation proceeds at a rapid rate until the upper film of soil is dry, then it gradually diminishes. The grasses and small vegetation continue to transpire water from the upper layers of soil into which their roots penetrate, at a continually decreasing rate. In the forest, on the other hand, a considerable

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* *Ibid.*, pages 96–102 and 132–135.

† *Ibid.*, page 81.

portion is caught in the tree crowns. After a shower the tree-tops first dry out at a rapid rate, then evaporation continues from the litter, etc., at about half the rate in the open, but continues for a longer time. Now, in every forest there is usually a heavy growth of underbrush, grasses, etc., — frequently as much small plant life as is found in the open, — and these transpire large quantities of water from the litter and upper layers of soil, while the deeper roots of the large trees draw from greater depths. Hence, compared with the open, the forest in general evaporates and transpires greater quantities of water than the open field, but from the fact that evaporation takes place at a slower rate in the forest, wooded glades are usually moist, not having an opportunity to dry out between showers. Because of this ocular evidence of moisture, the conclusion is hastily drawn that the forest is a great conserver of water, when, as a matter of fact, this moisture in evidence in the forest would either have run off or percolated into the soil if the forest were not there.

Whatever moisture is evaporated or transpired from an area is lost to the water supply of that region. It depends on conditions whether this reduction is useful or harmful. Any increase in percolation goes to increase the uniformity of the yield, and uniformity usually is a desirable element in the utilization of water supplies.

Effect on Rainfall. — Until recent years it was quite generally believed that forests increased precipitation. Even the most ardent advocates of that theory now generally admit that forests are the result and not the cause of rainfall, and that they do not influence the distribution of rainfall to any appreciable degree.

The physical causes of rain are not fully understood, but it is certain that the moisture in the air cannot be precipitated until the air is cooled below the "dew-point." Air will hold just so much water vapor at a particular temperature. Therefore if saturated air is cooled, part of the vapor is "squeezed out" of the air. If the cooling is slow, the vapor forms clouds of mist; if rapid, it forms drops which fall as rain or snow. Any influence which tends to cool large volumes of saturated air suddenly may cause rainfall. The most potent influence is dynamic cooling, i. e., by rising to heights where the pressure is less, allowing sudden cooling of air by adiabatic expansion; thus the windward sides of mountain slopes deflect the winds upward, and hence receive a large amount of precipitation if these winds are saturated.

Now, if forest cover induces rainfall, it must do it by appre-

ciably increasing evaporation, which increase must be precipitated over the same region, or the forest area by some peculiarity must divert rain to itself that otherwise would fall elsewhere. Now, forests do generally increase evaporation, but it is never a sufficient increase to materially affect the saturation of the air over them; yet it is plainly evident that, to increase rainfall by increased evaporation, the increase in evaporation must materially affect the condition of saturation of the surrounding air. On the second point it is hardly possible that the slight difference in temperature over the forest will produce dynamic cooling of air sufficient to induce rain.

Data on relative amounts of rainfall over forests and open land have been gathered for half a century or more. Only one conclusion can be drawn from them, — that, if this increase exists, it is less than the observational errors of the methods used, and hence is unimportant economically.

The mechanical effect of forests on precipitation, however, is not negligible. The first important truth is that the tree crowns catch considerable precipitation and dissipate it by evaporation. The long series of European experiments have shown that forest crowns catch about 25 per cent. of the annual precipitation. In other words, only about three fourths of the rainfall reaches the humus and litter. The exact amount of course depends upon the intensity of precipitation. The amount required to saturate the leaves and branches of a forest may be a larger percentage of a light summer shower, but would be an immaterial part of a heavy rainstorm.

The second feature for consideration is the mechanical retarding effect of the litter and underbrush on the run-off. Here again this effect must be weighed against that of the open field. The retarding influence of a sod or of a rocky slope is just as great as that of a forest litter. Under the leaves, twigs and débris of a forest floor, the water filters to lower levels just as surely and as rapidly as it will over the roughened surface of an open hillside with its attendant growth of grasses, weeds or small brush. Among large trees the mechanical retardation is much less than among the tangled undergrowth of open brushland. Moreover, such retarding effect can scarcely be useful even if it existed. Suppose it takes water thirty minutes to run down an open hillside, and suppose that if the same hillside were covered with forest and litter the time would be doubled, the maximum rate of flow in the stream at the foot of the hill would be just as great in the one case as in the other, only it may

be delayed a matter of minutes, or hours at most. To make stream-flow more uniform the retardation must be effective over much longer periods of time, — weeks or months rather than minutes.

Effect on Snowfall. — The mechanical effect of a forest on *snowfall* is of special importance. It is generally believed that because of the shade, wind protection and reduced temperatures within a forest, melting of snow is greatly prolonged and that the uniformity of run-off is consequently improved both by increased percolation induced and by the continued supply from slowly melting snow fields.

The advantages to percolation from melting snow are no greater than from rains. Snow itself will not percolate until melting occurs, and then the action under a forest litter is in no wise different than if the water were newly precipitated. This feature has already been discussed.

The mechanical influences of trees on snowfall are well known. The initial fall is caught in the crowns. If snow is dry and accompanied by wind, comparatively little is caught in the trees, but, if the snow is damp, enormous quantities are held in the branches. As much as six or ten inches of soggy snow may lodge in the trees and evaporate directly, none of it reaching the ground. Evaporation from snow is almost as rapid as from a water surface, and especially so when suspended in the trees, because of the greatly increased surface exposed. Thus generally the forest floor receives less snow than that in the open, as in the case of rainfall. But when snow does reach the ground it forms an even blanket over the surface and no appreciable drifting occurs. The longer the snow lies the more compact it becomes. A layer of snow five feet in thickness may in a few months of ordinary weather shrink to two feet without producing enough water to wet the ground underneath or causing any run-off. This is also true of snow in the open.

In the open land, however, the winds have free play, and snowdrifts are formed in every gully and in the lee of every obstruction. Exposed knobs or hill crowns may be practically bare, while in the drifts the snow may be ten times the average depth of snowfall. Thus a given volume of snow in the forest may have twenty times as much surface exposed to melting influences as if the same volume lay in the open.

When spring comes, the melting first begins in the open during the days, with freezing at night; while in the forest practically no melting occurs. As warm weather advances

the snow on the exposed portions in the open is gradually melted and the drifts begin to supply some water, but no floods can ever be caused from slow melting of deep snowdrifts. The snowdrift, especially in the higher altitudes, is an important conserver of precipitation. It continues to supply water to the streams long after the even blanket of snow in the forest has entirely disappeared.

The advance of spring under forest cover has an entirely different effect. The snow gradually compacts, the volume becomes less but without reducing the surface exposed. When warm weather really comes, and the temperatures during both day and night are above the freezing point, the even blanket goes off with a rush, frequently causing higher water than if the same volume had been deposited in the open. True, the maximum rate of run-off from the forest occurs later than if the area was open country, but the value of this maximum is generally greater. This delay might be useful if it extended the melting period well into the summer, but the delay is only a matter of a few days at most, and after it is past the flow diminishes much more rapidly than after the maximum from the melting of snowdrifts in the open.

Do Forests Diminish Floods? — This feature of the forest question has been touched upon in what has preceded, but the belief is so general that forests have an enormous influence in reducing the height of floods that the subject deserves special mention.

It may be true that the forest cover has a moderating effect on medium stages of a stream, but even this has not been demonstrated beyond question. Certain it is that great floods in rivers are not diminished in the slightest by forests on their headwaters. Great floods are always caused by excessive rainfall, frequently attended by sudden melting of snows. On the Pacific Coast the " chinook " wind is the most frequent cause of heavy floods. This has its counterpart in the "*foehn*" of Switzerland. There, dry, warm winds have been known to melt as much as three feet of snow in fifteen hours. Under such an influence the even blanket of snow in the forest is particularly susceptible to quick melting and gives rise to greater floods than the same volume of snow would from its usually drifted positions in the open country.

It requires a relatively small quantity of water to sufficiently saturate the litter in a forest floor to permit rapid run-off. It is not necessary that this forest litter become completely saturated

before run-off occurs. Mention has been made of the "thatch" that leaves sometimes form over the surface of a forest floor. This is particularly effective in deciduous timber after the spring snows have been melted. In our western forests I have seen large areas in the spring completely covered, almost as effectively as if shingled, by the leaves of maple, alder and other deciduous trees and brush. To a less degree the needles of conifers also may prevent complete saturation of the forest litter and humus before rapid run-off begins. But even if it be admitted that complete saturation must occur before water begins to run off, the amount of water so required is too slight to appreciably diminish the height of floods. It can only diminish the moderate freshets. These freshets are not the controlling feature in design of structures either for river improvement or the utilization of water supplies. It is always the maximum that governs.

On large rivers serious floods are produced by combinations of flood waters from tributaries arriving simultaneously. Such combinations result from the peculiar distribution of rains over the area and are beyond human control. In many cases retardation of the flood from a forested portion may cause a more disastrous combination than if that particular contribution had not been retarded. However, no general conclusions can be drawn from these circumstances, each area and each flood on it being a law unto itself.

If forests mitigate floods, they can only accomplish the result either by storing a considerable portion of the precipitation or by mechanically retarding the run-off to produce a beneficial combination. A uniform retardation over the whole area will not lessen the maximum run-off, it only delays the time of its occurrence, while a non-uniform retardation, as we have just seen, is just as likely to be harmful as beneficial. We have also seen that the storage capacity of a forest is very limited. In countries of heavy rainfall this storage, in so far as it does exist, is beneficial, but in countries where the total water supply is required, it is a positive detriment since this amount is not returned to the stream but is permanently removed from the water supply of the region.

Do Forests Increase Low Water Flow? — In view of the fact that the forest is a heavy consumer of water, and that the ground water level under a forest cover is substantially lower than in the open country, there is positively no evidence upon which to base an affirmative answer. During the summer months stream flow can only be maintained by drawing on

water previously stored in snowbanks and in the ground, or by the run-off from summer showers. In the open country snow-drifts continue to supply water to the stream long after the snow has disappeared from the forest.

The light summer shower certainly adds little to run-off from a forested region, for it is usually absorbed completely by the crowns and forest litter. But in the open country the same shower may produce considerable run-off or add something to percolating water.

Since the water stored in the humus is not returned to the stream, but is evaporated, the only thing left to increase run-off is the increment to ground water induced by a forest cover, and we have seen that this is small in any event and is just as likely to be a decrement. The conditions in summer in a forest are these: moist litter and top soil, dry stratum where tree roots penetrate, moist soil and ground water below. In the open country the conditions are: dry top soil, then moist soil merging into ground water. Of the two conditions, the open country will probably furnish the greater amount of percolating water, other things being equal. The difference, however, is seldom great enough to be of economic importance one way or the other.

Summary. — I will briefly sum up the pertinent points relating to the general influences of forests on climate, precipitation and run-off.

In spite of the general belief that forests have a great mitigating effect on floods, induce great lower water, and favorably influence the climate of a region, it is seen that a rigid analysis of the process by which this influence is said to be exercised leaves serious doubts as to the efficacy of forests to fulfill these claims. We have found that:

1. Forest litter and humus do not necessarily induce greater percolation of water into the underlying soil than would obtain in the open, and wherever it does have this effect the increment to ground water is offset by the excessive use of water by transpiration and for the growth of trees. In porous soils, a forest cover may effectively prevent percolation.

2. Forests may absorb and dissipate intermittent showers without permitting any run-off or percolation. In the open, however, such showers always produce some run-off or add something to ground water.

3. Ground water level in forested lands is lower than in the open, owing to excessive use of water for plant growth.

This reduces the water available for stream flow during the summer (growing season) and instead of adding to the low stages of streams, the forest in reality deprives the streams of the water so consumed.

4. Forests prevent the formation of snowdrifts, which is recognized as an important storage agency for keeping up the summer flow of streams. The melting of the uniform blanket of snow under a forest cover is somewhat delayed in time, but may induce higher floods than could possibly come from melting in the open.

5. Floods are not reduced by forests. Once saturated, the forest has no further ability to retain water, and the run-off proceeds as completely as in the open. The amount required for saturation is small and can only affect the medium freshets to a small degree.

6. The amount stored after each rain in the humus is not returned directly to the stream, and but rarely given up to the soil. It is virtually lost by slow evaporation and the transpiration from smaller plants on the forest floor.

7. The net effect of these influences is that the total run-off from a forested area is less than that from an open area, other things being equal, and that the uniformity of stream flow is not improved.

8. Forests do not increase precipitation. The influences they exert through increased evaporation, decreased temperature or convection currents are altogether impotent to accomplish this result. Precipitation is caused by forces of much greater magnitude.

Soil Erosion.

There is a widespread belief that forests are necessary for the prevention of soil erosion. But with this, as with the other features connected with the forestry propaganda, there is a wide difference between the actual benefits secured and those popularly attributed to the forests.

Only in a few special cases has it been proven that the mere cutting down of trees resulted in harmful erosion of the land. Wherever forests have existed in the past, some growth is sure to follow the removal of them. Such a growth is generally of different varieties, but its efficacy in preventing soil erosion is no less. All things considered, small underbrush and the tangled mass of ferns, vines, grasses and the other small growth

that inevitably follows logging operations or fire, are even more effective in preventing soil wash than the virgin timber.

In a few cases where soil is scanty, slopes steep, and rainfall abundant and intense, the delicate balance between permanency of soil and the tendency to wash is disturbed by the removal of trees, and erosion follows. Such instances, however, are specifically local, affect comparatively small areas, and it is not just to draw general conclusions from them.

It is only on sloping ground that there is any tendency to erode, in any event, and any kind of growth tends to prevent it. Experience has shown that grasses are more effective in preventing erosion by water than any other single agency. On the other hand, erosion by wind is more effectively prevented by large timber, while a dense cover of small brush, chaparral, etc., will prevent the combined effect of wind and water erosion better than either.

Erosion of soil by water results from the cultivation of lands, the building of roads, trails, logging chutes, etc.; and not from the mere removal of timber. This statement is worthy of emphasis. Erosion almost invariably results from some development process that man has initiated. I have seen deep gullies in a grass-covered field that began by water running in the wheel tracks left by one wagon driven over the surface. Elsewhere in the field the grasses effectively prevented soil wash. We can, therefore, only hope to prevent soil erosion in so far as we can dispense with these development processes.

Soil erosion has been an element in determining the topography of the country since time began, and will continue to be an important factor. All valley lands have been formed from soil washed from the adjacent hills. Rocks on the hills disintegrate and are gradually washed by rain and carried by the streams to lower elevation. Thus all agricultural lands have been formed. Where one part of the country is the loser, another portion gains by this process. We cannot prevent it and we ought not if we could. There is not the slightest evidence that the annual burden of silt and soil carried by the rivers of the country has appreciably increased since man's occupancy of it.

Forests are cut for some specific purpose. If for the timber only, a new growth soon springs up, even in the abandoned roads and trails, and in a few years heals all the scars man has made. If the area has been severely burned, this growth is delayed, but it will eventually follow and the erosion which has

increased during the time of recovery will gradually decrease until a balance is once more established. If the area is cleared for agricultural purposes, erosion may continue to the detriment of the owner, but some one else further down the stream is the gainer. We cannot dispense with agricultural lands, and the solution of the problem rarely lies in reforesting the area but in adapting agricultural methods to meet the conditions. The change from forest to meadow lands and pasture never increases erosion, and it is possible to so plow lands on fairly steep slopes that excessive erosion will not follow.

We hear a great deal about the rocks and débris from deforested hills filling the river channels and covering the rich valley lands. The careful observer will find the same thing is true where virgin forests exist, and in addition we have the river channels filled with drift, uprooted trees and timber débris of all kinds. Excessive flood heights in wooded countries are frequently caused by drift jams in the river channels, new channels are cut and valley lands flooded. Damages from such causes are not insignificant, and menace habitations contiguous to virgin forests as surely as those adjacent to cut-over lands.

In this matter our ills are purely relative. We cannot dispense with agricultural lands, and we cannot dispense with works of development and improvement; neither can we prevent soil erosion. Certain local conditions may be improved by local treatment. In many instances unnecessary damage has been done, but we must not draw the general conclusion from such isolated cases that the removal of forests is always a menace to the welfare of the country.

A Study of Existing Data on Forest Influences.

If the conventional forestry theory is correct, we should be able to detect the influences claimed for them in records of run-off from areas where material changes have taken place in the forest cover of the drainage area, during the periods of record. Such an analysis should deal with simultaneous records of precipitation and run-off covering a long period of years both before and after the change in forest cover occurred. As before stated, there is no fixed relation between run-off and precipitation, even on the same watershed. Each year precipitation is different in amount, distribution and intensity, and the run-off necessarily exhibits the same general fluctuations. These quantities, however, only fluctuate between certain limits;

hence if the records are accurate and of sufficient length the average for both conditions of forest cover should exhibit the changes, if any, for which the forest is responsible.

The unfortunate thing is, that existing records are not of sufficient accuracy nor of sufficient length and completeness to warrant an exhaustive analysis to determine the actual influence of forests. We cannot, therefore, expect to show the actual influence of a forest cover, but we can show the limit beyond which this influence does not extend, which is of no small importance. It will be found that this limit is infinitely small compared with the popular belief in its magnitude; that is to say, the actual influence of a forest in modifying run-off is too small to be detected in any existing records, while it is generally believed to be of the first magnitude and importance. The data used for this study are of the same quality as to accuracy and completeness as are those on which are based the expenditures of large sums in development works for the utilization of water supplies, and they are sufficiently accurate for those purposes. If, then, an influence is so obscure that it cannot be detected by the same process by which we secure the data on which are based the developments of water supplies, can this influence be of economic importance?

Two lines of inquiry will be followed: (1) as to the effect on the total yield of a drainage area; and (2) as to the effect on uniformity of flow. I have been unable to ascertain the exact claims made by forestry advocates as to the effect of forests on the total yield of a drainage area. In fact, the influence in this particular appears to be charmingly elastic. If forests exist in a humid country, they are said to increase the total run-off. In countries of scanty rainfall, they are said to decrease the total yield. Mr. Pinchot states, in his little book "The Fight for Conservation," page 53,

"The connection between forests and rivers is like that between father and son. No forests, no rivers."

This, perhaps, is not intended as a scientific view of the case, but the impression Mr. Pinchot would convey and the thing he would have the public believe is that forests increase the water supply.

In Bulletin No. 44, Bureau of Forestry, "The Diminished Flow of Rock River in Wisconsin and Illinois and Its Relation to the Surrounding Forests," page 9, the author says:

"On the whole, it is safe to say that a larger proportion of the

precipitation gets ultimately into the streams from a forest-covered region than from one that is unforested."

Mr. George W. Rafter, Water Supply and Irrigation Paper No. 80, "The Relation of Rainfall to Run-off," page 53, makes this statement:

"The extent of forestation has probably a considerable effect on the run-off of streams. With similar rainfall, two streams, one in a region having dense primeval forests, the other in a region wholly or partially deforested, will show different run-off. The one with the dense forest will show larger run-off than the stream in the deforested area. In some parts of the state of New York these differences may amount to as much as five or six inches in depth over the entire catchment area."

Mr. James W. Toumey, Year-book, Department of Agriculture, 1903, page 287, collaborator, Bureau of Forestry, says:

"In regions characterized by a short wet season and a long dry one, as in southern California and many other portions of the West, present evidence indicates, at least on small mountainous catchment areas, that the forest *very materially increases* the total amount of run-off."

The facts are, however, that if the forest has any influence at all, it is to decrease the total run-off in all cases, owing to the greater evaporation, transpiration and storage in the humus. On a watershed where forests have been removed, therefore, we should find a greater yield for the same precipitation.

This conclusion appears to be a rational one, and has in support thereof the well-known fact that forests are not found in regions where there is less than about 20 in. of rainfall per annum. Nature has made a wise provision in this respect. In well-watered countries the forests grow in profusion and help to diminish the total run-off by their evaporation, transpiration and humus storage. In such cases we are oversupplied with water and the forest aids in its dissipation. In regions of scanty rainfall, all the water is required and the forests are less luxuriant, or absent, hence a greater part of the precipitation is available for the uses of mankind.

The foregoing apply to the *total yield* of a watershed only, and must not be construed as applying to the uniformity of flow. On this point the pro-forestry advocates are unanimous in the belief that forests induce greater uniformity of flow. The agencies by which this is said to be accomplished have already been discussed. We will now examine the records themselves.

I submit below practically all the long-time records available, of both precipitation and run-off, on watersheds where a change in forest cover has taken place. There are not many examples of this kind. It is admittedly impossible to find out, without great expense, the actual amount of forest changes; nor is it important to know more than that such changes have occurred during the period of record and that they are material changes.

I have expressed the run-off each year as depth of water in inches over the entire drainage area, and the precipitation in the same unit. Divide one by the other and obtain the "run-off per inch of precipitation." It will be found that even under the same surface conditions this quantity will vary from year to year. This variation is due to the variation in amount and distribution of precipitation and to the resultant ground storage. If we start the year with full ground storage, a much larger proportion of that year's precipitation will run off than if the ground storage was depleted at the beginning of the year and had to be replenished. It takes a certain amount of precipitation to produce any run-off at all.

In arid countries large areas frequently receive from six to ten inches of precipitation each year and yet yield no run-off. There are a multitude of other conditions and factors, and it is obviously impossible to take them all into consideration. We will generally find that the run-off per inch of precipitation will itself increase or decrease with the precipitation; i. e., during wet years a larger proportion runs off than in dry years. In a long series of years, however, these influences tend to balance each other, and if the records include both forested and non-forested period, the effect of forests should be detected.

I have treated all these records in successive periods, inquiring first as to the change in the total quantity of run-off, and second as to the uniformity of flow.

Tennessee River Basin. — The records of discharge have been compiled from gage readings kept at Chattanooga, Tenn., by the United States Army engineers. Discharge measurements have been made by the United States Geological Survey, by which these gage readings are translated into mean discharges for each day of the year. The precipitation data are taken from records of the United States Weather Bureau.

The record covers thirty-five years, from 1874 to 1908. The most active lumber operations in the upper portion of the drainage basin have been carried on during the past twenty years. Before the seventies the forested areas in the mountainous

regions were practically the same as before the advent of white settlers. Since the beginning of the record, about 25 per cent. of the forests on the drainage area have been removed. The total drainage above Chattanooga is 21 400 square miles, of which about 60 per cent. is still in forest, some of which has been partially culled for certain species, and over which have run fires of more or less severity since the country was first settled. (These data taken from Professional Memoirs, Engineer Bureau, United States Army, Vol. 1, No. 4, page 398, and Professional Paper, United States Geological Survey, No. 72.)

I have chosen this stream because the records are reliable and because they have been used extensively by pro-forestry advocates as an example of the "calamities" that inevitably follow the ruthless destruction of our forests. According to Leighton (Water Supply Paper No. 234, page 23), the effect of deforestation on the run-off of this stream has been to increase the flood severity and flood frequency 18.75 per cent. since 1884. In my analysis I have used the identical figures for precipitation and discharge used by Mr. Leighton.

The following table gives the essential facts in regard to the run-off from this watershed. The entire interval of record has been divided into four periods, and the figures given are the averages for these periods as shown.

Tennessee River at Chattanooga, Tenn.

Drainage Area, 21 400 sq. miles.

Period.	Precipitation. (Inches.)	Run-off. (Inches.)	Run-off per Inch of Precipitation. (Inches.)	Maximum Discharge. (Sec. Ft.)	Minimum Discharge. (Sec. Ft.)	Uniformity Ratio.
1st nine years, 1874–1882 . . .	58.1	26.5	0.45	221 000	7.960	0.036
2d nine years, 1883–1891 . . .	51.7	27.4	0.53	242 000	8.660	0.036
3d nine years, 1892–1900 . . .	48.8	22.6	0.46	218 000	8.950	0.041
4th eight years, 1901–1908 . . .	49.9	24.5	0.49	191 000	9.990	0.052

The Tennessee basin is decidedly a humid region, and, if the current forestry theories are correct, we should expect to find a material decrease in the run-off per inch of precipitation separate and apart from that which would naturally follow the decrease in rainfall during the period. The rainfall records are not nearly so accurate as those of run-off, and too much signi-

ficance must not be attached to them, especially the earlier records. Apparently the run-off per inch was least when the rainfall was greatest (first period) and the area of forest cover was also greatest. This apparent result, while directly contradictory to the popular forestry theory, is doubtless due to inaccuracies in the precipitation records and we should not attach significance to it. Beginning with the second period we see that with a decreasing rainfall the run-off per inch also decreases as before pointed out. The forestry theory would lead us to believe that this quantity should increase with a decrease in the forest covered area, but such is not the case.

Fig. 1 shows the precipitation, run-off, and run-off per inch of precipitation, plotted for each year, together with the averages by periods, as given in the table. The general parallelism of these hydrographs is striking. It proves conclusively

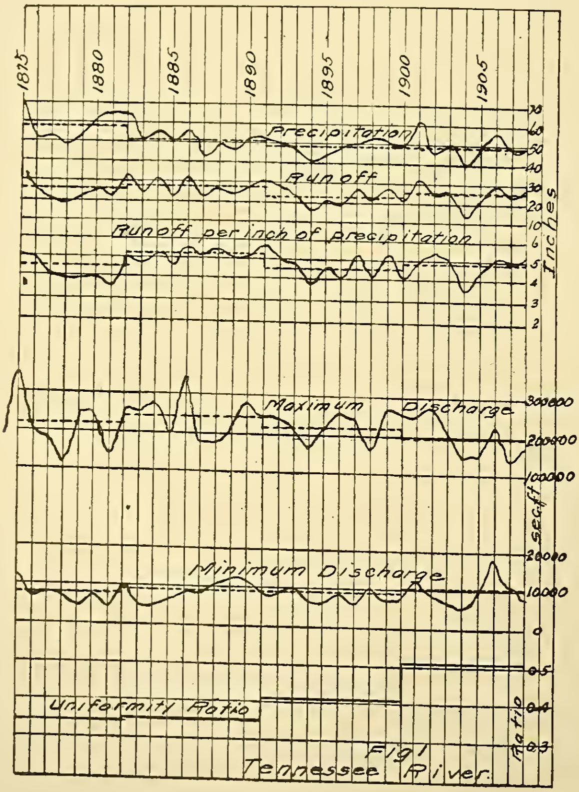

Fig. 1.

that variations in run-off are produced by variations in precipitation, and that if any other influence exists it is of no moment.

Inquiring next as to the uniformity of flow, the last three columns in the above table furnish interesting data on this point. The forestry theory teaches that forests induce lower high-waters and higher low-waters than would obtain without them. Column five gives the average maximum yearly discharge, and column six gives the average minimum yearly discharge, for each period. Column seven is obtained by dividing the minimum by the maximum, and is a measure of the uniformity of flow. It is therefore called the "uniformity ratio." A stream whose flow was the same every day (if such were possible) would have a uniformity ratio of 1.00, while a stream that went entirely dry would have zero as a uniformity ratio. Hence the larger this ratio, the more uniform the flow.

It is seen that this ratio has persistently increased coincident with a reduction in the forest area on the watershed. This directly controverts the forestry theory. On this stream flood-heights are substantially lower, and low-water flow materially higher, than when its drainage area was heavily forested. However, the cause must be looked for entirely outside of forestry effects.

This system of analysis does not take full account of the moderate freshets, only the maximums each year being considered. To take a proper study of this feature involves an enormous amount of labor, since daily records of discharge and precipitation would have to be critically analyzed and each freshet expressed in terms of the rain that produced it. This will involve also an arbitrary assumption of what constitutes a freshet, different assumptions as to this quantity yielding entirely different results.

Some such analyses of the Tennessee records have been made by both Prof. Willis L. Moore, chief of the United States Weather Bureau, and M. O. Leighton, of the United States Geological Survey. Each arrives at radically different conclusions by using the records since 1883. Evidently this is too short a period from which to draw conclusions. I shall present some data of this kind in connection with the records of the Merrimac River.

Ohio River Basin. — The records of precipitation on this watershed begin in 1830, and the records of gage readings at Cincinnati begin in 1858. The discharge data have been compiled from measurements made by the United States Army

engineers and by the United States Geological Survey. Gage records are found in publications of the army engineers and those of the weather bureau.

The extent of deforestation is unknown, but has been considerable. This river has also been held up by forestry advocates as an example of the injurious effects of deforestation. For that reason the records are of double interest.

The following table presents the data in similar fashion as for the Tennessee River, except that the total interval of seventy-eight years for precipitation data is divided into eight periods, and the fifty years of precipitation and run-off records into five periods.

Ohio River at Cincinnati, Ohio.

Drainage Area, 73 900 sq. miles.

Period.	Precipitation. (Inches.)	Run-off. (Inches.)	Run-off per Inch of Precipitation. (Inches.)	Maximum Discharge (Sec. Ft.)	Minimum Discharge. (Sec. Ft.)	Uniformity Ratio.
1st eight years, 1830–37.....	39.2					
2d ten years, 1838–47.....	40.0					
3d ten years, 1848–57.....	41.8					
4th ten years, 1858–67.....	43.8	17.0	0.39	419 000	10.150	0.024
5th ten years, 1868–77.....	40.3	15.8	0.39	407 100	10.720	0.026
6th ten years, 1878–87.....	41.7	19.0	0.45	476 400	8.900	0.019
7th ten years, 1888–97.....	41.3	17.0	0.41	405 500	10.510	0.026
8th ten years, 1898–1907...	39.7	16.7	0.42	462 900	11.000	0.024

Fig. 2 shows the hydrographs and the period averages in a manner similar to those for Tennessee River. The run-off per inch of precipitation has apparently increased coincident with a reduction in forest cover, which is directly opposed to the forestry theory, since this region is classed as humid. Now, if this was also accompanied by a decrease in the uniformity of flow, our forestry friends might even yet find comfort in the records. But such is not the case. The lowest uniformity coincides with the period of greatest run-off, in the sixth period. An examination of the hydrograph will show high precipitation and high floods in 1882–3–4. Now, if this is due to removal of

forests, why were not the years 1890–1 also noted for high floods? Surely there was less forest area in 1890 than in 1882. The reason lies in the intensity and nature of precipitation, and not in the slightest degree in forestry influences. The general parallelism of the precipitation and run-off curves indicates that the former is the first, last and only cause of the

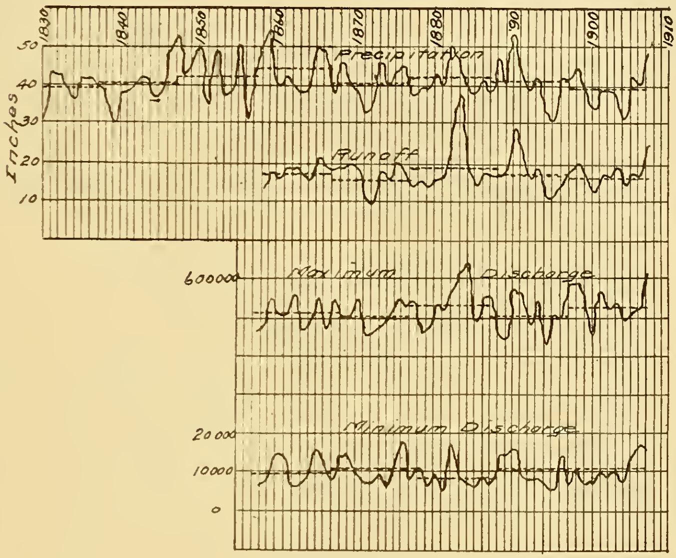

FIG. 2. OHIO RIVER.

latter. The amount of the one in the main governs the amount of the other, while variations in the nature and intensity of the one are reflected in variations in the run-off per inch of precipitation. The vegetation on the ground surface has too small an influence to be detected.

Ottawa River Basin, Canada. — In connection with the proposed Georgian Bay Ship Canal, the Department of Public Works, Canada, has compiled the discharge of Ottawa River above Besserer's Grove (nine miles below Ottawa) from 1850 to date, and the precipitation on the watershed from 1866 to date. (Georgian Bay Ship Canal Report for 1908, Plates 30 and 56; also Progress Report, 1909–1910, page 41.)

No detailed estimate of the amount of deforestation that has taken place on this watershed has as yet been made, except that it is known to be considerable. At one time the entire watershed was heavily forested with spruce, pine, etc. Lum-

bering operations have been carried on extensively for the past thirty years at an increasing rate. The river valleys in the lower reaches have for the most part been cleared for agricultural purposes, yet the percentage of reduction of forests on this watershed is not great, but may be taken at about 10 per cent. during the period of record.

The total drainage area above the gage is 45 500 square miles. There are numerous lakes on the watershed, some of them being of large extent. A large part of the precipitation is in the form of snow, and the spring thaws cause annual rises of varying magnitude. They nearly always reach a maximum in May.

The treatment is similar to that followed for Tennessee and Ohio rivers.

OTTAWA RIVER AT BESSERER'S GROVE.

Drainage Area, 45 500 sq. miles.

Period.	Precipitation. (Inches.)	Run-off. (Inches.)	Run-off per Inch of Precipitation. (Inches.)	Maximum Discharge. (Sec. Ft.)	Minimum Discharge. (Sec. Ft.)	Uniformity Ratio.
1st ten years, 1850–59.....		16.72		144 300	19 900	0.138
2d ten years, 1860–69.....		16.38		161 000	19 700	0.122
3d ten years, 1870–79.....	28.58	15.80	0.55	168 000	16 100	0.096
4th ten years, 1880–89.....	32.71	16.50	0.50	165 800	21 200	0.128
5th ten years, 1890–99.....	31.71	17.12	0.54	166 700	20 500	0.123
6th ten years, 1900–09.....	31.13	16.78	0.54	153 000	19 200	0.125

In Fig. 3 are shown the corresponding hydrographs.

The high uniformity of flow in this stream, compared with those heretofore considered, is accounted for by the large percentage of lake surface on its area. These are the true equalizers of the flow, and not the forests. The lowest uniformity is coincident with a period of highest precipitation, viz., 1878 to 1882, and certainly this was before any material reduction in forest cover had occurred. The fourth period, however, shows the highest uniformity (except the first) and this must not be given too much weight because of the inaccuracies of the earlier records. The whole record shows no change either in total run-off or in uniformity of flow that can in any degree be attrib-

uted to the removal of forests. In fact, the reduction of forest cover on this stream is comparatively slight. The head-waters are still covered with virgin forests.

Murray River Basin, Victoria, Australia. — On this watershed progressive deforestation has taken place during the past twenty-five years. Climatically, the country is semi-arid. The waters of the stream are extensively used for irrigation,

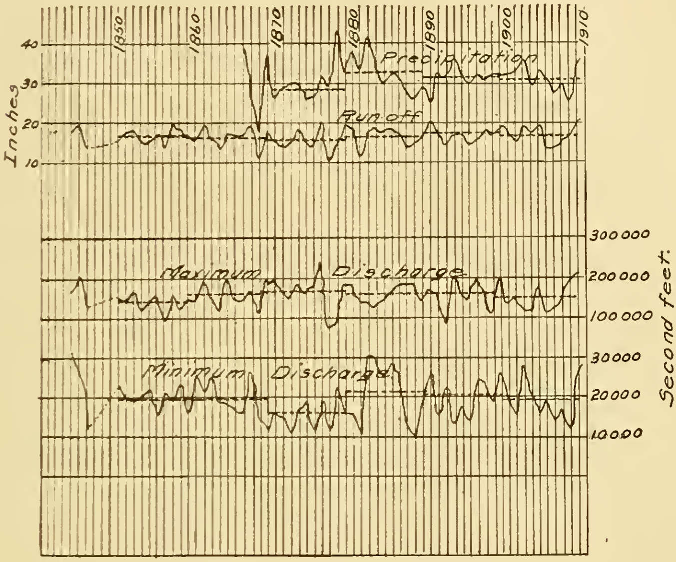

FIG. 3. OTTAWA RIVER.

by both gravity and pumping systems. On this account it will not be admissible to use minimum discharge, nor the total annual yield, since this quantity is more or less under artificial control. The flood discharges, however, can be safely used in a study of this nature. The official records, compiled under the direction of Stuard Murray, M. Inst. C. E., chief engineer of the Rivers and Water Supply Commission of the state of Victoria, have been used.

The practice of ring-barking (to kill) the trees on large areas in this region has been in force for many years. Some American engineers (*Engineering News*, October 1, 1908, Proceedings of Annual Convention, New England Water Works Association), personally familiar with the practice, state that it is extremely common in Australia and has been done to increase the stream flow. Dr. Elwood Mead, the present chief

engineer of the Water Supply Commission, in a letter to me (February 11, 1911), states that the real reason is to "improve the pasturage. The live trees shade the ground and draw sustenance from it and thus reduce the growth of grass."

It is impossible to ascertain in detail the amount of deforestation during the period of record, but it is known to be quite extensive.

MURRAY RIVER, AT MILDURA, VICTORIA.

Period.	Mean Annual Discharge. (Sec. Ft.)	Average Maximum Discharge. (Sec. Ft.)
1st twenty years, 1865–85......	11 800	28 900
2d twenty years, 1886–05......	11 150	26 500
Change in 2d period...........	6 per cent. decrease	9 per cent. decrease

The decrease in mean discharge has undoubtedly been due both to decreased precipitation and to diversions above the gage. The records of precipitation do not begin until 1883, and this is too short a period from which to draw conclusions. The significant truth in the above table is that the flood heights have decreased during the period of record coincident with the removal of forests, instead of increasing, as the forestry theory teaches. This, however, cannot be attributed to the removal of forests, but is due to variations in the amount and intensity of rainfall during the two periods, and doubtless to regulation resulting from the construction of storage reservoirs in the watershed for irrigation purposes.

Merrimac River Basin. — Lieut.-Col. Edw. Burr, United States Army Engineers, has made an exhaustive report on "an investigation of the influence of forests on the run-off in the Merrimac Basin" (House Document No. 9, 62d Congress, 1st Session, "Merrimac River, Mass., between Haverhill and Lowell") from which the descriptions and data are taken. The latter have been arranged to conform to the manner of representation adopted for this report. We have the analysis of precipitation and of total yield and uniformity, and in addition are able to present data on the variations of moderate freshets or medium floods.

The basin of Merrimac River lies both in New Hampshire and in Massachusetts. The headwaters are in the rugged White Mountain region, and the middle and lower valleys are rolling country with some areas of lake surface and small swamps.

The underlying rock is gneiss and granite. Over these lies glacial drift of sand, gravel and bowlders, frequently mixed with finer materials, and covered in the valleys with alluvium clays and other soils brought down from higher elevations. A large portion of the valley lands are, or have been, agricultural, while the uplands are unfit for any growth except forests on account of the great masses of bowlders and other glacial débris that cover the surface.

Originally the entire area was in forest. When the Pilgrims arrived in New England "they were much comforted, especially seeing so goodly a land and wooded to the brink of the sea." As population increased, deforestation of the land steadily progressed to secure agricultural land and to supply commercial lumber. After a time, owing to western competition, a decline in both lumbering and agriculture set in and large areas that were once tilled are now grown up to brush and timber, some of the timber being already of commercial size. These facts are well known, but the author of the above-mentioned report has instituted a very careful study of the statistical data, and expresses his conclusions thus:

> "Deforestation [of Merrimac River Basin] continued progressively from the earliest settlements to about 1860–1870; reforestation through natural processes has progressed since 1870 at a rate which has increased from 1880 to 1900 or later; and the forest areas are larger now than in 1860–1870 by as much as 25 to 30 per cent. of the entire basin." *

In New Hampshire, which is practically representative of the Merrimac basin, the forest area has changed as follows:

FOREST AREA IN NEW HAMPSHIRE. (*Ibid.*, page 15.)

	Percentage of State.	Percentage Change.
1850	45.1	....
1860	43.1	2.0 decrease
1870	43.1	0.6 increase
1880	46.0	2.3 ,,
1890	59.1	13.1 ,,
1900	67.4	8.3 ,,

The discharge and run-off data have been compiled from gage records kept by the Essex Company below its dam at Lawrence, Mass., since 1849. Discharges computed over the dam and through the wheels and millraces of the company and by

* *Ibid.*, page 15.

actual discharge measurements since 1888, serve to translate these gage heights into mean daily discharges, from which the run-off has been computed.

The precipitation data are taken from reports of the United States Weather Bureau and from records kept by the power companies along Merrimac River.

The following table gives similar data to those presented for the other basins discussed.

Merrimac River at Lawrence, Mass.

Drainage Area, 4 660 sq. miles.

Period.	Precipitation. (Inches.)	Run-off. (Inches.)	Run-off per Inch of Precipitation. (Inches.)	Maximum Discharge. (Inches.)	Minimum Discharge. (Inches.)	Uniformity Ratio.
1st nine years, 1850–58.....		24.60		47 800	2 160	0.045
2d ten years, 1859–68.....	41.20	23.21	0.563	42 900	2 430	0.057
3d ten years, 1869–78.....	40.88	22.94	0.562	46 400	2 500	0.054
4th ten years, 1879–88.....	40.91	21.70	0.530	34 100	2 340	0.069
5th ten years, 1889–98.....	41.99	22.15	0.528	40 600	2 270	0.056
6th ten years, 1899–1908...	40.04	21.90	0.547	43 100	2 190	0.051

In Fig. 4 are shown the hydrographs for this stream.

Again the direct relation between precipitation and run-off is apparent from the general parallelism of these two curves. The total run-off per inch of precipitation shows a slight decreasing tendency coincident with an increase in forest cover. This is opposed to the forestry theory and substantiates the belief that forests use large quantities of water, and hence always reduce the run-off. However, it is much more reasonable to believe that these changes are due to variations in precipitation and have occurred entirely independent of the forests. The uniformity ratio is seen to be highest when the forest area was least, in the fourth period, but the hydrographs show this to be a period of low rainfall, which readily accounts for it. The uniformity of flow on this stream has not sensibly changed during the period of record. The slight variations must be attributed to the precipitation and not to forests.

We are able to present some very interesting data on the frequency and height of moderate floods of Merrimac River, in

addition to those of maximum heights given in the foregoing table. To do this rationally, it is first necessary to define what constitutes a flood. The commonly accepted definition of a flood is such a rise in a river that lands not usually covered are overflowed. Usually a "danger line" is fixed, above which damage is likely to occur. Obviously such a danger

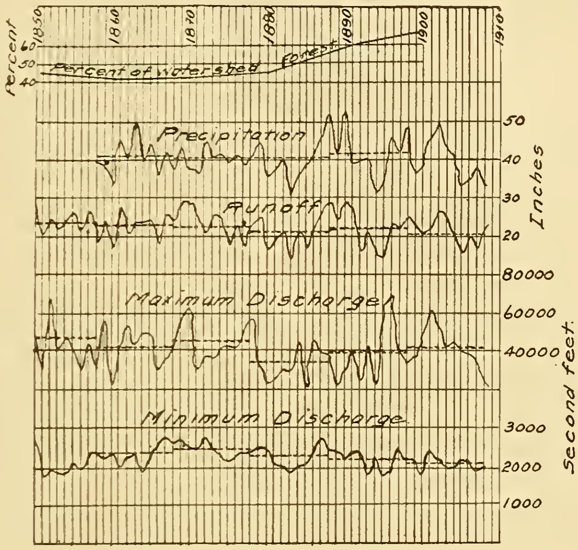

FIG. 4. MERRIMAC RIVER.

line is purely arbitrary and usually the developments on the banks of the stream are the governing factor. In an uninhabited country there would be no danger line. However, it is necessary to fix such a limit above which the river would be called "in flood" and below which the river would be normal or in moderate freshet. On the Merrimac River the gage height of 15 ft. has been fixed as a danger line. I quote from Colonel Burr's report, page 24:

". . . It was determined to class as floods only such rises as reached or exceeded a height of 15 ft. on the gage and to consider such a rise as constituting only one flood between the times it passed 8 ft. on the gage in rising and again in falling. In computing flood durations and discharge, consideration was given only to the period during which the river was above gage 10 ft. These arbitrary limits were assumed after a thorough study of the hydrograph for the entire record, and are believed to provide a fair basis for the analysis of flood characteristics. The effects that might result from the use of other

similar limits are unknown, since no others have been tried, but there is no reason to expect that any other set of standards, selected within rational limits and without regard to results, would lead to conclusions of a different character."

The following table gives the essential facts adduced in Colonel Burr's analyses:

FLOODS ON MERRIMAC RIVER.

Period.	Number of Floods (above 15 ft. on Gage).	Number of Days per Year Floods were above 10 ft. on Gage.	Average Annual Run-off during Floods. (Inches.)	Percentage of Flood to Annual Run-off.
1st nine years, 1850–58........	22	65.1	10.33	42
2d ten years, 1859–68.........	14	61.2	9.63	41
3d ten years, 1869–78.........	16	62.8	10.20	44
4th ten years, 1879–88........	13	54.1	8.32	38
5th ten years, 1889–98........	13	49.2	7.49	34
6th ten years, 1899–1908......	15	56.2	9.24	42

The last column in the above table gives the average proportion of each year's yield that ran off as flood discharge. If the forestry theory is correct, we should see a progressive decrease in this percentage since the forest area on the watershed has increased, but the table shows the same percentage during the last period as obtained in the first, yet the forest area was 30 per cent. greater.

There appears to be a period from 1850 to 1860 when floods were more severe than in later years. There also appears an increase in flood severity coincident with reforestation. Floods are always produced by peculiar and erratic climatic combinations, and the slightly higher frequency in the first, third and last periods is due solely to such combinations and not in any degree to forest influences.

I quote below the conclusions at which Colonel Burr arrived in his report, page 31:

"Deforestation of the basin continued progressively from the early settlements until about 1860–1870, and since that period forested areas have increased through natural causes by 25 per cent. or more of the entire basin, notwithstanding the continuance of lumbering operations.

"There has been no decrease in precipitation in the basin as a result of deforestation or any increase with the reforestation of 25 per cent. or more of its area. The precipitation for fifty to ninety years at points within the basin or within a few miles of its borders shows tendencies or cycles that bear no relation to the changes in forest areas.

"The average run-off through the river varies with the precipitation over its basin, and the percentage of run-off to pre-

cipitation is not appreciably affected by forest changes as great as 25 per cent. or more of the basin.

"The frequency of floods has not been decreased by reforestation or increased by deforestation.

"Exceptionally high floods have occurred at intervals without respect to forest conditions. Flood heights have not been decreased by forestation or increased by deforestation, and the principal characteristics of floods are unaffected by forest changes. The duration of flood stages and the amount of run-off during such stages have not been affected adversely by deforestation or beneficially by reforestation.

"Deforestation has not lessened the height of the river at low water or increased the duration of low-water periods, and the reforestation of 25 per cent. or more of the basin has not had any beneficial effect on low stages of the river.

"Variations in stream flow are determined essentially by variations in climatic conditions which move in irregular cycles independent of forest changes."

Sudbury River Basin, Mass. — This stream is utilized for municipal water supply for the Metropolitan District of Boston, Mass. The data are taken from reports of the Metropolitan Water and Sewerage Board. About one half of the Sudbury watershed is woodland, the remainder is farm waste area and water surface. Some artificial reforestation has been recently undertaken. However, the change in wooded area since 1875 is of no consequence.

In this case, therefore, we are dealing with a watershed whose forested conditions have remained the same during the period of record.

The data are of exceptional accuracy and are given merely to show that the same degree of variations in total run-off and in run-off per inch of precipitation is found on streams where no change in forest area has occurred. Owing to artificial storage on the watershed, the uniformity of flow cannot be investigated with the data in hand.

SUDBURY RIVER AT FRAMINGHAM, MASS.

Drainage area, 1875–78, 77.76 sq. miles.
1879–80, 78.24 sq. miles.
1881–1909, 75.20 sq. miles.

Period.	Precipitation. (Inches.)	Run-off. (Inches.)	Run-off per Inch of Precipitation. (Inches.)
1st nine years, 1875–83	43.7	20.1	0.46
2d nine years, 1884–92	47.9	25.0	0.52
3d nine years, 1893–1901	47.6	22.9	0.48
4th eight years, 1902–09	42.9	19.0	0.44

The run-off per inch of precipitation is seen to vary as greatly on this area as on those where extensive changes in forest cover have occurred. These changes are seen to compare very favorably with those on the Tennessee basin. The periods are almost identical and the yield per inch of rainfall is nearly the same for each period. In this watershed, however, the conformity to variations in precipitation is much more marked, which is doubtless due to the greater accuracy of the data.

Lake Cochituate Basin. — The watershed is tributary to Sudbury River, but is more level. No change in forest cover has taken place on this area. The surface conditions are somewhat similar to those of the Sudbury watershed, mixed woodland and farm areas, some brush and swamp land, with a large percentage of water surface.

The area is smaller, however, and presents different characteristics of absolute run-off than larger areas, but the changes year by year are just as instructive.

The run-off data are quite accurate, but the precipitation data prior to 1871 are somewhat questionable. The figures have been compiled by the Metropolitan Water and Sewerage Board of Boston.

Lake Cochituate, at Cochituate, Mass.

Drainage Area, 18.9 sq. miles.

Period.	Precipitation. (Inches.)	Run-off. (Inches.)	Run-off per Inch of Precipitation. (Inches.)
1st eight years, 1863–70	56.3	22.2	0.394
2d nine years, 1871–79	44.9	20.4	0.454
3d ten years, 1880–89	43.4	18.9	0.435
4th ten years, 1890–99	46.0	20.4	0.443
5th ten years, 1900–09	43.3	18.3	0.423

The variations in the run-off per inch of precipitation are seen to be just as great as in the case of the Merrimac, Ottawa, Ohio or any other river we have heretofore considered, but without the corresponding change in forest cover.

Croton River Basin. — This watershed is fully utilized for the municipal water supply of New York City. The area is partly wooded and partly farmed, with some waste and brush land. A large portion of the annual yield of the basin is impounded in reservoirs. Records have been kept of the precipitation and run-off since 1868, and are known to be fairly accurate.

There has been no appreciable change in the extent of woodland on the area during the period of record. Whatever small changes have occurred have been to increase the wooded portion, but they are too slight to be given weight.

The following table gives the results, divided into five periods. (Taken from Water Supply and Irrigation Paper No. 80, page 86, and *Engineering News*, May 18, 1911.)

CROTON RIVER AT CROTON DAM.

Drainage Area, 338.8 sq. miles.

Period.	Precipitation (Inches.)	Run-off. (Inches.)	Run-off per Inch of Precipitation. (Inches.)
1st eight years, 1868–75	45.6	23.5	0.52
2d nine years, 1876–84	46.2	20.0	0.43
3d nine years, 1885–93	51.8	25.3	0.49
4th nine years, 1894–1902	50.6	26.0	0.51
5th eight years, 1903–10	47.6	23.9	0.50

The run-off per inch of precipitation does not vary greatly in absolute amount, and the averages appear to vary almost independently of the precipitation. Like the other areas discussed, the variations in run-off are caused by other factors than forests.

Periodic Variations. — The foregoing examples constitute practically all records of long standing where simultaneous run-off and precipitation data are available. A study of them will reveal a tendency towards periodic variations. It is well known that wet and dry years occur in groups. Although an extremely wet year may succeed an extremely dry one, or vice versa, the tendency toward cycle or secular variations is very evident. This phenomenon has an important bearing on the question of forests and water supply, chiefly because facts and data are often arrayed against the memory of the oldest inhabitant to establish or refute a theory of this nature.

It is an almost universal belief that the climate is changing; that floods, rainfall, temperatures, etc., are all "different than they used to be." No matter where one goes, the same statement is heard. It is a perfectly natural conclusion, and results from two causes, one psychological, the other physical. As we grow older, our perspective undergoes an adjustment. We only retain impressions of those things that are associated in our memory with particular circumstances. "Man marks when he hits, but never marks when he misses." We recall wading snowdrifts to school. To-day those snowdrifts do not seem so deep and we immediately conclude that they are not.

The water in the "old swimming hole" was much deeper when we were boys; to-day it is only waist deep and we think the river is smaller than it used to be. We visit a spring, after a lapse of years, from which we drank when boys; it doesn't seem so large nor the water so fine as then. The spring is the same, but our conception of it has changed. Our memory of it is fixed by some isolated circumstance connected with it, while to-day we view it in the abstract, unconsciously comparing it with others we have seen since. A man's memory of high and low stages of rivers alongside of which he has always lived is invariably governed by isolated circumstances and incidents which he does not remember consecutively. For this reason such evidence is always untrustworthy, and only those who have had occasion to gather evidences of this kind know how conflicting and untrustworthy they are.

The second and principal reason for the universal belief that physical phenomena are changing is that they are actually undergoing continual changes, not, however, to the degree nor

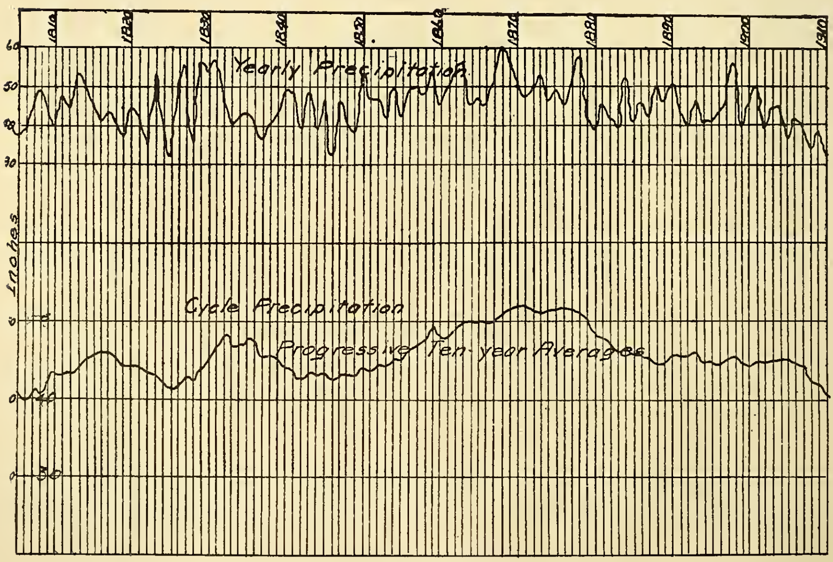

FIG. 5.

in the manner that is popularly believed. Rainfall, temperatures, humidity, winds, and consequently the stages of rivers and lakes, occur and recur with variable length and intensity. The major cycles are longer than the life of an average man, —

at least longer than his faculty for accurate recollection. Yet it is largely on such memories and on such data that the forestry and similar theories are frequently based. For this reason it is well to inquire briefly into the matter.

In order to show the secular variations in physical phenomena, I have prepared two diagrams. Fig. 5 is a graphical representation of the rainfall along the Massachusetts coast since 1804, made from the records of New Haven, New Bedford and Boston. This constitutes a record of one hundred and seven years, and is the longest reliable record in the United States. The precipitation each year is shown in the upper curve. The lower curve represents the cyclic variations. Each point on it is an average of the preceding ten years, that is, the average for 1814 to 1823 is shown opposite the year 1823, etc. This is done in order to bring out the progressive cycle tendency of the rainfall.

Fig. 6 shows graphically the changes in water level of Lake Michigan and of Great Salt Lake, Utah. These large bodies of water rise and fall with the major variations in run-off, evaporation, etc. They do not reflect minor variations, and therefore possess an averaging influence on these physical phenomena.

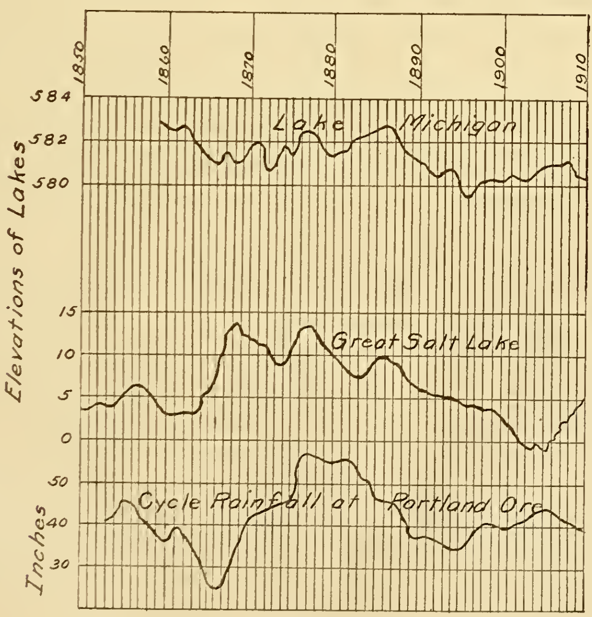

Fig. 6. Climatic Variations.

Great Salt Lake steadily fell from 1868 to 1905, and the general impression there is that the lake is drying up. But it was probably lower in the forties than in 1905. Since the latter date it has steadily risen. In order to show that these variations do conform to the cyclic changes in precipitation, I have shown the cycle rainfall (five year averages) for Portland, Ore. The water supply for Utah comes from the Pacific Ocean, and the Portland records or any other good record in the path of the vapor-bearing winds will indicate the yearly variations.

These two curves are approximately parallel, and show in a striking manner how closely related are the major climatic cycles and how broad their zone of influence. The changes in level of Lake Michigan and in precipitation on the Atlantic coast show a general correlation with those of precipitation and lake levels on the Pacific Coast. The causes of these variations are beyond the scope of man's endeavor. The mere cutting or planting of trees, tilling of land, or anything that man undertakes, will not nullify or modify the physical laws that govern these phenomena; his influence is limited to the uppermost film of the earth's crust. His greatest effort can scarcely effect material changes even there and certainly cannot reach into the realms of earth and sky wherein originate the mighty forces that affect these phenomena.

From a study of the foregoing diagrams it is easy to see how one's impressions of the changes in climate will depend altogether upon the length and vividness of his memory. On the New England coast, for example, he who could remember back into the seventies would feel sure that the rainfall is less now than formerly; but if "now" was in the seventies, his impression would be exactly reversed.

These secular changes explain some of the progressive tendencies noticed in the run-off from the rivers heretofore cited. Thus the rainfall and run-off on the Tennessee River appear to have persistently decreased since the beginning of the record in 1875, a period of generally high rainfall. If the record extended back thirty years farther, it would tell a different story. The Ohio record shows the same tendency, rising from 1860 to 1880 and gradually falling since. The precipitation record extends back much further and shows the same general tendency as seen in the New England record. The run-off would follow the same law if the record was of sufficient length.

Uniformity of Flow. — I wish to present briefly a few data

on this subject, since it is the main issue so far as forestry effects are concerned. I have chosen streams in pairs, existing under the same climatic conditions, some with forested drainage areas and some without forests.

Of course it is futile to draw conclusions or to attempt to obtain a measure of forestry effects from such comparisons; nevertheless the causes of uniformity of flow are well worth an investigation.

On the streams chosen, long records are not available, nor are they necessary. A comparison of simultaneous records for even one year is justifiable if the streams are subject to the same climatic influences.

The absolute values of run-off are of no moment in this inquiry, neither is a comparison of precipitation vital. To obtain a measure of uniformity of flow, a certain period has been selected, and the run-off for each month of that period has been expressed as a percentage of the total. These percentages have then been added successively, giving a "mass curve" of monthly run-off.

Silvies and Blitzen rivers lie in central Oregon. They flow from opposite directions into Malheur Lake. Both have about the same range of elevations. The topography is not unlike, and the soil and geologic structure are comparable. The Blitzen watershed has no trees at all, while the Silvies

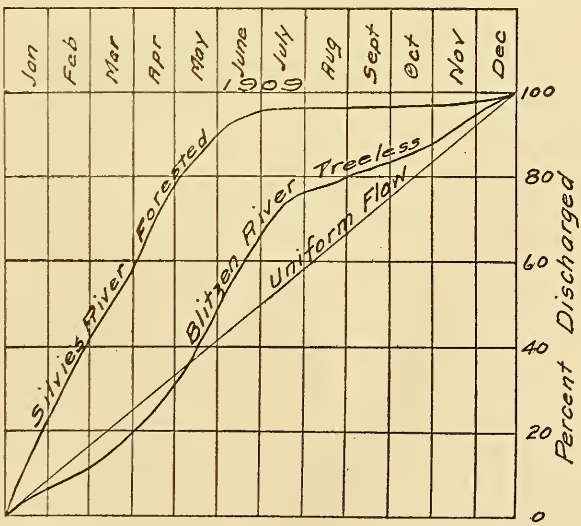

FIG. 7.

watershed is fairly well forested. Each receives about the same rainfall. Simultaneous records for 1909 have been used. The Blitzen River has a drainage area of 238 sq. miles, and discharged 77 100 acre ft. of water. Silvies River drains 450 sq. miles, and discharged 73 600 acre ft. in the same period.

Fig. 7 shows the uniformity characteristics of the two streams. If the flow was absolutely uniform, the curves would follow the straight line, that is, a constant percentage of the total flow would be discharged each month. The nearer the discharge curve follows and parallels this line, the more uniform is the flow. It is seen that Blitzen River without forests is very uniform, while Silvies discharged nearly all the water in the first six months of the year. (Where the curve is horizontal, it indicates that nothing is being added to what has already passed.) Measured by our former standard of uniformity, i. e., the ratio of the minimum to the maximum, we find the uniformity factor for Blitzen River was 0.075, and of Silvies River 0.00079; that is, the uniformity of Blitzen River, without forests, is one hundred times greater than the forested Silvies River. The principal reason for this lies in the fact that the Blitzen area is cut into gullies and canyons into which enormous quantities of snow are drifted each year. These melt gradually and keep up the flow. If the area were timbered, a great deal of this drifting would be prevented and it is

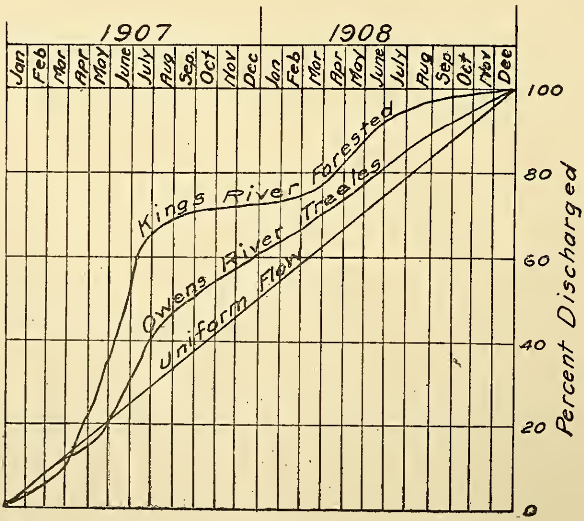

FIG. 8.

not likely that so great a uniformity would obtain. Certain it is, the differences of soil and topography can never account for this great difference in flow. It is also seen that the yield per square mile of the Blitzen River is over twice that of the Silvies. The effect of dissipation of water in this semi-arid region by forests is material in this case; however, it is doubtful if it will account for this difference in total yield.

I do not contend, by any means, that this difference in flow characteristics is accounted for by forest cover. It is due mainly to other causes. The effect of the trees in preventing snowdrifts on Silvies watershed tends to decrease its uniformity of flow, but it is only a tendency, and I do not believe the absolute effect of this factor will account for more than 10 to 15 per cent. of the difference in uniformity of flow.

Fig. 8 is a similar diagram for Kings and Owens rivers, of California. Kings River drains 1 740 sq. miles of densely forested mountainous country on the western slope of the Sierra Nevada Range. Owens River drains about 450 sq. miles of treeless country of the opposite side of the range. The general topographic and geologic features of the two regions are similar, although the Kings River watershed receives a great deal more precipitation in the year than does the Owens

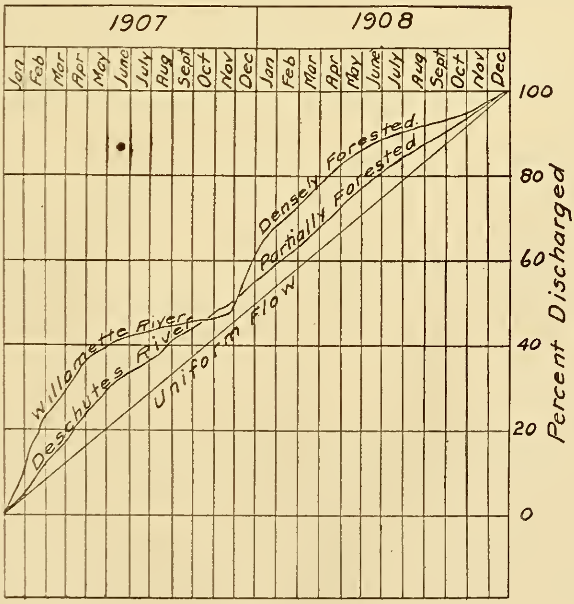

FIG. 9.

River basin. The temperatures on the eastern side of the range are generally lower than those on the western.

Owens River is remarkably uniform in flow, as will be seen from the figure. The ratio of minimum to maximum during this period, 1907–8, which includes a high and a low year, was 0.146. Kings River, on the other hand, is subject to enormous floods and the minimum flow is comparatively low. Its ratio of minimum to maximum during the same period was only 0.0163. That is, the uniformity of Owens River is ten times that of Kings River.

This difference is decidedly unfavorable to the forest theory. However, we must look elsewhere for the explanation. The soil porosity and underlying rocks and the ruggedness of topography are similar on the two areas. The causes of the difference are found in the differences of temperature and precipitation. The flow of Owens River is maintained during the summer by huge snowdrifts that accumulate in the gullies and canyons of its area. The process of drifting is not interfered with by a forest cover. This interference, although a minor factor, is not immaterial.

We will next compare two forested watersheds. Willamette and Deschutes rivers of Oregon, both flowing north, parallel to the Cascade Range; Willamette River drains 4 860 sq. miles on the west, Deschutes River drains 9 180 sq. miles on the east. The Willamette watershed is densely forested, while the Deschutes is only partially so. The topography of the areas does not differ greatly, but the overlying soils are radically different.

Deschutes River is remarkably uniform in flow. Willamette River has no such distinction. The years 1907–8 include both a high- and a low-water year. The uniformity ratio of Deschutes River during this period was 0.180, while that of the Willamette was only 0.014, less than one tenth as large. Fig. 9 shows the uniformity diagram for these streams, from which the wonderful uniformity in the flow of Deschutes River is apparent.

The differences in uniformity of flow of these streams are not due to forestry effects, for the less uniform stream has fully double the extent and density of forest cover. The cause is found in the soil cover and underlying rock structure. The Deschutes area is covered with a thick layer of porous pumiceous soil, presumably blown eastward by prevailing winds during early periods of volcanic activity. Under this pumiceous

cover lie the porous lava rocks. Together they provide such an abundant ground storage that the flow of Deschutes River scarcely varies from season to season. Whatever effect the forest has is to prevent soil absorption. The forest humus is less porous than the soil and therefore tends to prevent water from filtering into the soil. If we cover a pile of sand with fine dust, the dust acts as a shield to prevent infiltration.

On the Willamette watershed the soil is finer and more compact. The capacity for ground storage is not nearly so great as on the Deschutes area. The forest cover, if it has any effect at all on this watershed, probably has a tendency to aid infiltration. This effect, however, is more than offset by the mechanical interference of the forests with snow drifting. The final result would probably be a slightly greater uniformity in both streams if the forests were removed. The difference, however, would be too slight to be of any importance.

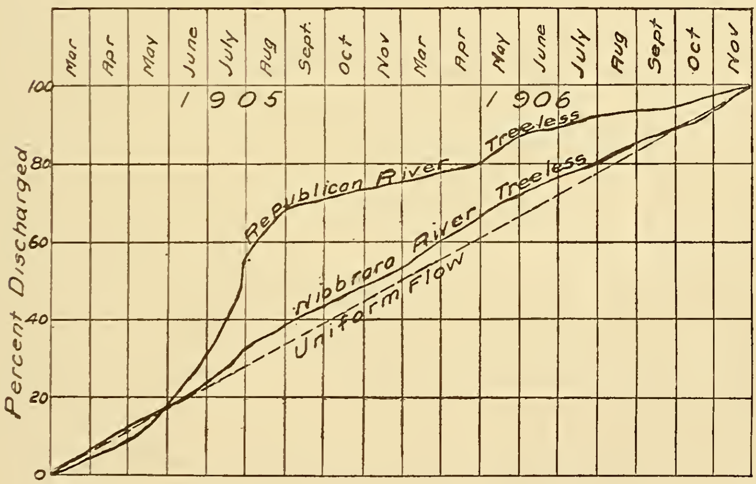

FIG. 10.

I will give one more example. The Republican and Niobrara rivers of Nebraska are radically different in their characteristics of flow. Both exist under the same general climatic conditions. The Republican River drains 22 300 sq. miles of rolling desert plains. Niobrara River drains 6 070 sq. miles of rolling sand hills. Neither area has forests or even woodlands of any description. The average precipitation and average

temperatures on the two watersheds are almost identical. Niobrara River is remarkably uniform, while Republican River is as singularly erratic. Winter records are not available on either stream and have simply been omitted, but the flow of both was near the lowest. Fig. 10 shows the uniformity diagram. The great uniformity of Niobrara River as contrasted with that of Republican River is readily seen. The uniformity ratio for the period chosen was, for Republican River 0.0061 and for Niobrara River 0.114, or nineteen times as great. This great difference in uniformity of flow is evidently not due to forests, for there are none there. It is due to one potent factor, — the soil cover. The sand area of the Niobrara watershed is probably from 20 to 100 ft. in thickness. This absorbs the precipitation as fast as it falls, and feeds the streams with seepage water at a nearly constant rate. A forest cover on this watershed would be a detriment, if it has any effect at all, so far as uniformity of stream flow is concerned.

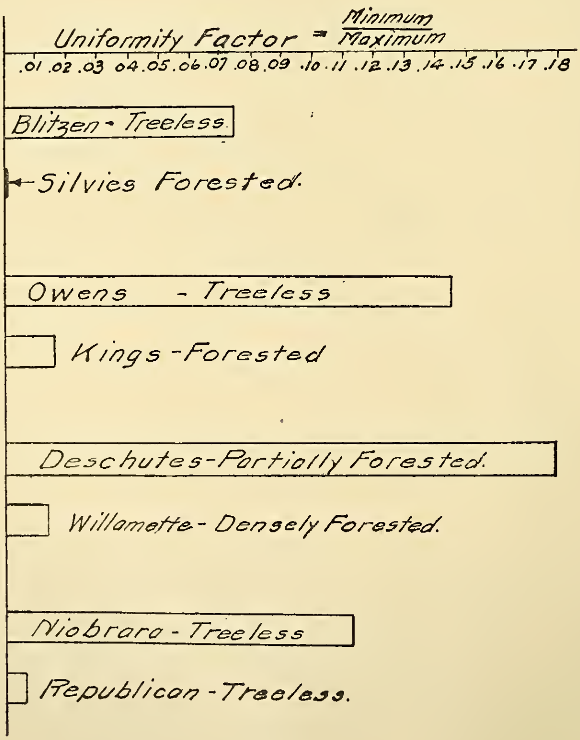

FIG. 11.

The Republican watershed has no such capacity for ground storage. The soil is thin and compact and the area is not rough and broken. Huge snowbanks cannot form, — in short, the area has no storage capacity in any form. An erratic, non-uniform stream flow results.

The foregoing examples show conclusively that uniformity of stream flow is influenced, practically in total, by factors entirely independent of forests, and if forests have any influence at all on this feature, it is very insignificant. The tendency they do possess, though almost infinitesimal, would be in a helpful direction in some cases, in others in a harmful direction.

In order to sum up concretely the essential facts as brought out under this caption, I have prepared Fig. 11. The uniformity factors (ratio of minimum to maximum) for the examples cited are shown to scale. Remembering that the larger this ratio, the more uniform the flow, the diagram needs no further explanation.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by August 15, 1913, for publication in a subsequent number of the JOURNAL.]

INTERCOASTAL CANAL.

By Warren B. Reed, Member of the Louisiana Engineering Society.

[Read before the Society, February 10, 1913.]

The Intercoastal Canal, or Inland Water Route in its broader sense, is now a definitely adopted plan projected and partially completed by the federal government, which when finished will extend from Boston, Mass., to the Rio Grande River at the Mexican border.

We will consider to-night, however, only that portion which has been inaugurated and promoted by the Interstate Inland Waterway League, which covers that section of the canal from the Mississippi River to the Rio Grande; and, even more particularly, the eastern portion which lies within the confines of Louisiana, as being of more immediate interest to us.

Even before the Civil War there was a canal constructed in Texas from Galveston to the Brazos River, and at least two in Louisiana, leading from the Mississippi River westward, but the plan for a continuous inland canal did not assume definite shape until several years later. This plan seems to have been conceived primarily with a view of having a protected inland water route for the transportation of war supplies, and the credit for its strategic value is given to Gen. Ulysses S. Grant. At all events, the demand was such that a government survey was made in 1873, under the supervision of Capt. C. W. Howell, and estimates submitted.

The magnitude of the enterprise, together with the cost, in those days of primeval dredging machinery, was such that the project was not undertaken and was apparently forgotten.

It was in 1897 that a gentleman from Corpus Christi, Tex., Mr. Louis Cobolini, chanced upon this report and suggested to Governor Culberson of Texas that he call a meeting for the purpose of revising the project. The meeting was called in Corpus Christi, and the Louisiana and Texas Congressmen and Senators at once became active and finally secured authorization for a re-survey. The survey was not completed until 1906 and was reported by Major Jadwin under date of May 6, 1907.

In the meantime the Interstate Inland Waterway League was being organized, and the first meeting was called by Mr. C. S. E. Holland, of Victoria, Tex.

The Louisiana advocates of this enterprise could not participate in this convention for the reason that we were under quarantine at the time, and consequently another meeting was held in May, 1906, at Lake Charles, where the League, as we know it to-day, was formally organized. From that day until the present time, the members of this League, both in Louisiana and Texas, have worked in harmony, side by side, holding annual conventions first in Louisiana and then in Texas, and it has been due to their efforts that the present progress has been made.

Foremost among the workers of this enterprise are Mr. C. S. E. Holland of Texas, Messrs. Henri Gueydan and Leon Locke of Louisiana, and it is due to their judgment, breadth of vision and indefatigable energy that this great public development is now on the high road to a successful completion.

The first appropriation from the government was in the Rivers and Harbors Bill of 1907, when, after having been turned down by the Board of Engineers for Rivers and Harbors, a re-hearing was obtained leading to a favorable report. This first appropriation was for $750 000, half of which was to be used between Galveston and Pass Cavallo in Texas and the other half between the Mississippi and the Mermentau rivers in Louisiana. Since that time each rivers and harbors bill has carried an additional sum, the total amounting to $1 687 000. Funds that are now available for use in Louisiana are $100 000, to be expended between the Teche and Mermentau rivers, and $417 450 for the completion of the work on the canal between the Mermentau River and the Sabine. The pending rivers and harbors bill has an additional appropriation of $190 000 for the completion of the work between the Mermentau and Calcasieu rivers. In Texas the canal should be completed as far as Houston this spring; the extension beyond Corpus Christi has not been authorized, but the surveys have been made.

In the preliminary report of Major Jadwin the route of the canal utilized, as far as possible, the present navigable waterways. The first route selected was up the Mississippi River through the Plaquemine Locks, and thence to Morgan City via the Atchafalaya River, up the Teche to the vicinity of Franklin, thence through one of several possible routes to be selected, to Cote Blanche Bay; through Cote Blanche Bay and Vermilion Bay to Schooner Bayou; thence to White Lake; through White Lake to Grand Lake; thence across Cameron Parish to Calcasieu Lake, with a further extension to Sabine Lake.

To those who are familiar with the navigation of these waters,

this route held many objections. In the first place, it is 165 miles from New Orleans via Bayou Plaquemine to Morgan City, against the swift stream of the Mississippi River and down the swift current of the Atchafalaya. In the second place, the navigation of Cote Blanche and Vermilion bays is possible for small craft in smooth weather only; similar though less serious objections are to be had to White Lake, Grand Lake and Calcasieu Lake. Therefore it has been the constant endeavor of the League to have this route modified by first making a direct route to Morgan City; second, eliminating Cote Blanche, Vermilion bays and the other large bodies of water, with the prime object in view of having a uniform, inland, slack water *canal* route, protected at all times and navigable under all weather conditions.

The League has met with constant coöperation and support in this undertaking from the United States engineers who have been in charge of this district, notably Col. Lansing H. Beach and Major Edward H. Schulz, the present officer in charge. At present there is a favorable report from this office before the engineers for rivers and harbors advocating a direct route from New Orleans to Morgan City, and a route eliminating Vermilion and Cote Blanche bays. The appropriation for these routes, however, has not yet been obtained, and the League is now engaged in the effort to secure this most important legislation.

As soon as a continuous canal is obtained the efforts of the League will be centered on obtaining a greater width and depth of canal, a standardization of width and length of locks, clearance above water level of fixed bridges and the width of horizontal openings of drawbridges. The locks on the canal must be of sufficient length and width to accommodate boats that are now in trade on the intersecting rivers and bayous, in order to allow through transportation and to avoid the expensive breaking of bulk freight.

The government engineers, in their requirements for right of way, have been wise in their demand for a 300-ft. reservation of continuous width, which will leave ample room for enlargement to accommodate the enormous traffic which will be carried on this water course within a few years.

The direct route from New Orleans to Morgan City is of paramount importance not only to the territory traversed, but to the commerce beyond Morgan City. While it is true that the commerce of the Teche and Morgan City can reach New Orleans via the Plaquemine Locks and the Mississippi River, this route has the disadvantage of swift currents to contend with

whether the freight is going to or coming from New Orleans. The Atchafalaya River is tortuous and so swift at times of high water that navigation is difficult and dangerous. The same applies, to a less extent, to the Mississippi River. Furthermore, the distance is about 165 miles, while the direct route would be about 85 miles. The short slack water route would obviate the danger to navigation, and in case of the sinking of a boat or barge the cost of floating it would be small, while with the present route the entire loss of the vessel would be almost a certainty.

The route via the Plaquemine Locks, while it affords relief to the commerce of the Teche, does not afford any relief to the territory traversed by Bayous DeLarge, Grand Caillou, Little Caillou, Terrebonne, Lafourche and the numerous large bayous lying between the Lafourche and the Mississippi River that afford water routes for the oyster industry and farm products. The territory from Bayou DeLarge to New Orleans probably contains more navigable waterways than any other equal number of square miles in the Union, and at present the only outlets for this network of navigable waterways are the two toll canals owned by private corporations, connecting them with the Mississippi River at New Orleans. In other words, the two private corporations control many miles of free navigable waterways, and from the fact that they have connected them by a short canal and locks with the Mississippi River, they levy a tax upon all the commerce. It is not my intention to decry the enterprise of the two corporations who, at considerable expense, have afforded a connecting link with these waterways and New Orleans. They were, before the days of railroads, the only means of transportation, and are now carrying a large commerce that would be undeveloped were it not for the facilities that they provide. My contention is, however, that these natural water routes should be so connected that those who are engaged in transportation thereon should have the opportunity of carrying their freight to a port — its logical destination. These navigable waterways in question have no natural port, and therefore the connecting link, giving access to New Orleans on the one side and Morgan City on the other side, has become an imperative necessity. This argument becomes still stronger when it is taken into consideration that such connections will result in the completion of a short and safe slack water route between the large commerce of the Teche and western Louisiana and New Orleans, making it the logical route of the Intercoastal Canal.

The natural water routes of southeastern Louisiana differ from those of other locations in that they have been the means of building up the lands along their banks instead of eroding the territory through which they flow, as the other streams and rivers. The land in this territory that is above tidal overflow lies along the banks of these bayous. It follows that the only land in cultivation, the plantations, villages and the towns, all lie immediately along the banks of these navigable streams and consequently have natural water transportation. Water transportation, in this territory, would compare to a railroad system provided with spur tracks running by every plantation and farm in a country of different geological formation.

This is illustrated by the number of landings on the Teche within a distance of 70 miles, where besides the towns of New Iberia, Jeanerette, Baldwin, Franklin, Patterson and Morgan City, there are 278 landings composed of 180 plantations, 5 villages, 54 miscellaneous factories, 9 sawmills and 32 sugar refineries.

The two and one-half million acres of marsh lands which are subject to tidal overflow that lie between these navigable streams have not as yet been reclaimed for cultivation. This tremendous undertaking, however, has been started and has attained considerable momentum. The pioneering has been done, their wonderful fertility, the moderate cost of reclamation, and the absolute success of the methods employed have been proven. Large capital in increasing quantities is buying these lands and many companies are now in process of actual development. The additional wealth that will be added to this territory by this means is almost inconceivable. The tonnage within the next decade over the same number of square miles will be several times that of the present tonnage. The reclamation of these lands will multiply the navigable canals, necessarily constructed for the purpose of building levees, until the entire territory will become a network of slack water canals.

This vast area will, therefore, be a veritable Holland, with its present navigable waterways interlaced with a network of navigable canals surrounding artificially drained farms. The direct route of the Intercoastal Canal is needed as a trunk line to carry all of this commerce, in addition to that produced on the present waterways. This is emphasized when it is borne in mind that building a network of railroads over this marsh land is not now practicable.

There are at present in the parishes of Lafourche and Terre-

bonne, lying directly on the banks of these navigable waterways, 160 000 acres of cultivated lands. These produce annually, besides other products, 1 200 000 tons of cane and over 100 000 tons of sugar. A great deal of this cane tonnage now goes by rail to the central factories, and all of the hundred thousand tons of raw sugar goes to New Orleans. Two years ago there were produced on the banks of Bayou Lafourche over 600 000 sacks of onions and potatoes, amounting to approximately 1 000 000 bushels. This is in addition to other farm products, such as corn. The excess corn raised on the banks of Bayou Lafourche and shipped the same year was over 200 000 bushels, and on Bayou Terrebonne, over 50 000 bushels.

Document No. 1163, 60th Congress, Second Session, in a letter to the Secretary of War, gives the value of the commerce of Bayou Terrebonne for one year as amounting to $17 812 000.

The following tables, made up from actual data that were obtainable, give an approximate idea of the volume of business directly along the route of the Intercoastal Canal.

The freight shipped into this territory, based upon the freight paid by the sugar plantations, which excludes freight of the villages, towns and stores, averages $2.50 per acre for the amount of land cultivated. This would make the ingoing freight into Terrebonne and Lafourche parishes, paid by the plantations alone, amount to $400 000.

Tonnage Produced between the Teche and Mermentau along Route of Canal at Present under Consideration, together with Tributary Waterways now Navigable.

	Tonnage.	Value.
Rice	175 58c	$6 673 201
Molasses	14 000	336 000
Sugar	46 750	3 740 000
Cane	550 000	2 200 000
Salt	200 000	600 000
Corn	312 440	4 299 400
Potatoes	16 000	204 000
Cotton and by-products	10 000	1 342 500
Straw and hay	10 000	50 000
Oysters and fish	3 000	30 000
Cattle and hogs	15 000	1 700 000
Furs and hides	....	100 000
Fuel oil	135 000	810 000
Timber	220 000	280 000
Lumber	52 500	682 500
Total	1 760 270	$23 047 601

TONNAGE PRODUCED BETWEEN FRANKLIN ON THE TECHE AND NEW ORLEANS, TOGETHER WITH THE TRIBUTARY WATERWAYS NOW NAVIGABLE.

	Tonnage.	Value.
Rice	6 470	$258 740
Molasses	62 500	1 500 000
Sugar	213 000	17 040 000
Cane	2 500 000	10 000 000
Corn	78 050	1 114 920
Potatoes and onions	48 000	612 000
Cotton and by-products	25 400	3 403 600
Oysters and shrimp	99 222	2 976 000
Fuel oil	5 400	32 400
Timber	2 700 000	3 700 000
Lumber	671 200	8 724 600
Furs and hides	....	400 000
Cattle, hogs and hay, no definite data.		
Total	6 409 242	$48 762 260

The banks of these navigable bayous, such as Terrebonne, Lafourche and others, are probably the most densely populated and highly cultivated agricultural lands in the Union, and their yield per acre, both in tonnage and value, exceeds by far any farm lands in the United States.

The available lands for reclamation and cultivation lying between the Atchafalaya River and the Mississippi are over two million and a half acres, at least two million acres of which will be drained and put into cultivation at moderate cost, and will, without question, be completed and in cultivation within the next two decades. Their enormous fertility, the mild and healthful climate and the increasing price of farm lands throughout the Union, will hasten this work, and this section of Louisiana will be, without question, the "garden spot" of this continent.

Referring to the tonnage produced to the west of Morgan City, it is alone of sufficient volume and importance to justify this short route to New Orleans, even should the territory between produce no tonnage. The enormous quantity of timber and mineral wealth combined with that of the farm products that necessarily must seek the port of New Orleans demands the continuation of the course of the Intercoastal Canal in as direct a route as possible. It also demands a slack water route that is not subject to the difficulties and dangers of navigation such as is offered by the Atchafalaya and Mississippi rivers.

The tonnage of cypress lumber produced on the banks of the Teche and its tributaries is greater than that produced between Gibson and New Orleans. The sugar tonnage produced

on the banks of the Teche and its tributaries is double that produced in the parishes of Lafourche and Terrebonne. If to this tonnage, therefore, is added the freight for the towns and factories as well as the other farm products, it will be seen that this tonnage is extremely large for the amount of mileage traversed by the stream. Connecting with the Teche will be the tonnage from the Intercoastal Canal to the westward. This consists of the rice crop, the sulphur, the oil and the salt, as well as the general merchandise of a vast area of country.

As a further illustration of the immediate development of business that will follow the completion of a continuous canal route, I have a letter from the Myles Salt Company which together with the Salt Mines of Avery's Island illustrates the advantages that will come when the Intercoastal Canal is completed past their doors, and shows how the output of these mines is limited by the number of cars that a single line of railroad finds it convenient to furnish, combined with the excessive freight rates that limit the shipping distance of the products. These two mines have at present an annual capacity of from seven to eight hundred thousand tons of various grades of rock salt, but their output is only two hundred thousand tons per annum, and it is stated that even with this output they are greatly hampered at times for lack of cars and transportation facilities. With the Intercoastal Canal opened from the Mississippi River to Port Arthur, within a very few years the output would be raised to the present capacity, that is, from two hundred thousand to eight hundred thousand tons, together with an additional tonnage amounting to practically one-half million a year.

Since the opening of the Plaquemine Locks, much of the tonnage produced upon the Teche has sought this water route, two lines of steamboats having entered this trade. The immediate result of this water transportation was a reduction of all the freight rates over the existing railroad. As an illustration, the rate on sugar from the Teche to New Orleans has been for many years 11 cents per 100 lb.; the water route via Plaquemine Locks is 9 cents. This will make a saving to the sugar planters of the Teche of over $80 000 per annum. With the direct route from Morgan City to New Orleans, this saving would be more than double. The reduction in rates on all other commodities is far greater than that on sugar.

The most important feature of this canal development, perhaps, is the nature of the transportation. On the Mississippi River and the Great Lakes, where water transportation prevails,

the hauling of the freight is done by transportation companies, and the shipper is practically in the same relation to the transportation company as in the case of railroads. The tonnage is hauled to certain fixed points, and its shipment depends upon schedules, freight rates and accommodations of the carriers. On this Intercoastal Canal Route, on the other hand, while there will doubtless be trunk lines of steamboats and barges, each and every farmer and merchant will have, at small expense, his own barge or barges, his own gasoline boats; his produce will be loaded in front of his door and carried to its final destination or to some shipping point. To an almost unlimited extent, therefore, the transportation will be in the hands of the many, and each individual will be entirely independent of commerce regulated by corporations. From the standpoint of the general welfare of the community, I cannot conceive of any greater economic advantage.

[NOTE.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by August 15, 1913, for publication in a subsequent number of the JOURNAL.]

STATE OFFICIAL COÖPERATION TO SECURE PROPER VALUATION UNDER ACT OF CONGRESS, MARCH 1, 1913.

By D. F. Jurgensen, Member of the Civil Engineers' Society of St. Paul, Minn.

The importance of the valuation of the property of the carriers about to be undertaken by the Interstate Commerce Commission, pursuant to the Act of Congress, March 1, 1913, may be summed up by the statement that upon it depends whether private ownership of railroad properties is to continue in the United States.

There can be little question that the carriers will seek to obtain a valuation to be used as a basis for rates which will at least approximately bear the same relation to present capitalization as did the cost of reproduction new, found by the Master in (the Minnesota Rate cases) Shepard *v.* Simpson and the allied cases.

To understand what this means, it is only necessary to state the following: The total capitalization of the Northern Pacific, Great Northern, and Minneapolis & St. Louis Railway systems, the last confined to Minnesota, was, at the time the actions were commenced, $596 041 096.66; the cost of reproduction new found by the master, $931 396 422, or 156.26 per cent. of the total capitalization; the total capitalization of railways in the United States (Poor's Manual) is $18 890 850 293; 156 per cent. of which is $29 518 842 667.84, excess $10 627 992 374.84. Speaking of this method for arriving at a basis of rates, Commissioner Lane, writing for the Interstate Commerce Commission in the Western Advance cases, 20 I. C. C. Rep. 307, said, page 339: " . . . In the face of economic philosophy, if stable and equitable rates are to be maintained, the suggestion has been made that it would be wise for the government to protect the people by taking to itself these properties at present value rather than await the day, perhaps thirty or fifty years hence, when they will have multiplied in value ten- or twenty-fold."

For many years there has been a persistent demand for a physical valuation of railroad property as a basis for rates. There has also been a somewhat smaller group of persons who advocated government ownership. The carriers, recognizing

the importance of the valuation, either as a basis for rates or price to be paid for the property if taken over by the government, have been quietly preparing for the valuation, and are now thoroughly organized with a central committee and prepared with unlimited resources to do their utmost in shaping the methods of the investigators and securing results which will be satisfactory to the private interests involved.

The stake is equal to the value of an empire, for if we compute the annual return allowed by the Circuit Court in the cases I have mentioned, viz., 7 per cent. upon the difference between even capitalization and cost of reproduction new at the ratio already given, it amounts to more than $743 000 000.

It is a matter for congratulation that the Act of Congress hereinbefore referred to provides for such a segregation of different elements of value that there is afforded a magnificent opportunity for arriving at the actual truth upon this most important subject.

This act provides, first, for a detailed inventory of each item of actual property and that as to each there shall be ascertained, (*a*) original cost, (*b*) cost of reproduction new, (*c*) cost of reproduction less depreciation and an analysis of the methods adopted and all reasons for difference in value; second, as to lands, it is provided that there shall be ascertained, (*a*) original cost, (*b*) present value, (*c*) original and present cost of condemnation and purchase and damages; third, an inventory of all property held for other purposes, and as to that original and present cost, including an analysis of the same; fourth, a history of the organization, issue of stock and cognate questions; and, fifth, a statement of all gifts, donations, including right-of-way, received by each carrier.

A compliance with the Act of Congress will necessarily result in such a comprehensive analysis of each item of property and of every element of value entering into it that there can be little doubt that a basis will be afforded for the determination of many questions still unsettled.

It will then be possible to ascertain the effect which would follow if carriers are allowed a return upon actual present value of all property; what portion of said present value consists of what has been designated as unearned increment; what portion of said present value consists of property donated by the public for presumably the public benefit; what justification there is for assuming the necessity of reconstruction, including such fictitious items as multiples on land values, interest during

construction, contingencies, enhanced unit prices and similar assumptions, and the actual relation which capitalization bears to original cost as well as present value.

The Interstate Commerce Commission, while having inquisitorial powers, may still upon many of these questions be compelled to base its conclusions upon such evidence as is produced before it. A concrete example of this is land value. Of necessity, the Commission, as well as the experts appointed by it, will have to pass upon the value of land in communities as to which they have no detailed knowledge. Trained experts will present evidence to the Commission upon behalf of the carriers upon this subject and it becomes pertinent to inquire who will present evidence upon behalf of the public. We have a situation in which a board exercising judicial powers will be presented with evidence upon behalf of one of the parties to the controversy, but left entirely to its own resources as to evidence upon behalf of the other party.

The railway commissioners all are familiar with conditions in their respective states, and can with the utmost propriety represent and protect the public in each state in this proceeding, which is in reality a contest between the carriers and the public, with the Interstate Commerce Commission as the Court or umpire.

This can only be done through coöperation. The carriers are fully prepared and thoroughly organized. The commissioners of the various states should follow their example; by so doing, the time for performance of the task will be shortened. Full and complete information will be secured and furnished to the Interstate Commerce Commission, and by thus protecting the rights of the public in each state, the aggregate public rights will be safeguarded.

Dated at St. Paul, Minn., May 24, 1913.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by August 15, 1913, for publication in a subsequent number of the Journal.]

OBITUARY.

Charles Albert Allen.

Member Boston Society of Civil Engineers.

Charles Albert Allen died December 9, 1912, at his home in Worcester, Mass., where he had resided during his entire life of nearly sixty-one years. He was a son of Albert Salisbury and Eliza (Cole) Allen; and was born in Worcester, January 27, 1852.

He was educated in the public schools of Worcester, finishing his studies at Worcester Academy, from which he graduated in 1869. He began his practical experience upon surveys for the Massachusetts Central Railroad in 1870, and in 1871 was appointed assistant engineer to the Worcester & Nashua Railroad, being promoted in 1873 to the position of chief engineer, which office he held for three years. He then became a member of the firm of Allen & Chase, contractors.

On January 7, 1878, Mr. Allen was elected city engineer of Worcester, to which position he was annually reëlected for fourteen years. While city engineer he was frequently called as consulting engineer to advise upon water supply and water power problems, sewerage and sewage treatment works, and upon questions relating to the elimination of grade crossings of various steam railroads. In the fall of 1892, having nearly completed his fifteenth year as city engineer, he resigned that office to devote his entire time to private practice. During his term of office, in addition to giving attention to the multitude of important engineering problems constantly arising in a rapidly growing industrial center, he gave particular study to the problems of water supply, sewage treatment, and the elimination of grade crossings.

In 1883 when the city of Worcester was being sorely pressed by litigation to introduce a sewage treatment plant to so treat the sewage before its discharge into the Blackstone River that it might not create a nuisance, the city council requested Mr. Allen to investigate the general problem of sewage treatment both in this country and abroad; in response to which request Mr. Allen made a tour of inspection in England, France and Germany, visiting the principal sewage treatment works of those

countries. As a result of his investigations he advised the treatment of the sewage of Worcester by chemical precipitation, and planned and built a plant for this purpose. This was a pioneer work, as no plant for the treatment of the sewage of a large city had been designed in this country prior to that time.

Pursuant to an order of the city council, passed in 1890, Mr. Allen served as a member of an engineer commission to investigate the problem of the elimination of grade crossings within the city, and in 1892 presented a voluminous report in which a general plan for the elimination of the grade crossings of the city was described.

After severing his official connection with the city government at Worcester, Mr. Allen was constantly engaged as consulting engineer upon his specialties in engineering. He was appointed, by the Superior Court of Massachusetts, upon forty-three grade crossing commissions, and was a frequent witness in court proceedings involving expert engineering testimony.

He was also engineer of the emergency works installed by the city of Worcester in 1911 to safeguard the water supply of the city in the face of the long and severe drought which had continued for several years and still prevailed at that time.

As a Mason, member of several social clubs and warden of St. Mark's Methodist Episcopal Church, Mr. Allen took an active part in the social life of the community and was brought into intimate contact with his fellow men, in whom he took a keen interest and for whom he always had a pleasant and inspiring word.

Mr. Allen married in 1875 Miss Grace T. Chase, daughter of Joseph and Rachel T. Chase, and five children were born to them. Mrs. Allen and four children, Robert C., Chester S., Mary H. (Benchley) and Grace M. (Toucey), survive him.

William Wheeler,
Harrison P. Eddy,
Committee.

May 21, 1913.

George Albert Kimball.

Past President Boston Society of Civil Engineers.

Mr. George Albert Kimball, past president of the Boston Society of Civil Engineers, died on December 3, 1912, after a very short illness.

Mr. Kimball gained his prominence in his chosen profession through hard, conscientious and constant work and effort during all the years of his practice. The sterling qualities of enterprise, honesty and fair dealing which brought him so prominently before the engineering societies are those of which Americans in general, and New Englanders in particular, are proud to acknowledge as the sound and basic principles on which not only men of Mr. Kimball's characteristics are founded, but those on which the country in general has grown to its present greatness.

Mr. Kimball was born on May 14, 1850, at Littleton, Mass., his father being William Kimball and his mother Mary A. (Lawrence) Kimball. His earliest known ancestor in America was Richard Kimball. His great-grandfather, Daniel Kimball, was a first lieutenant during the Revolution of 1775.

Mr. Kimball's early life on the farm at his home in Littleton gave him that love of nature which he maintained throughout his life. His business education was probably started in the typical country store in Littleton, of which his father was proprietor and who also served the town as town clerk and selectman. Mr. Kimball was fond of relating his experiences in trading the farm products in his youth, both in Littleton and in and about Boston, and some of the shrewd trades that he had made resulted in making life-long friends with his customers.

His education was obtained in the public schools in Littleton and in Appleton Academy in New Ipswich, N. H., preparing for the second year at Dartmouth College, but, owing to ill health, he was obliged to give this up.

Mr. Kimball started in his chosen profession of civil engineering in 1869 as rodman on railway surveys in Massachusetts. In 1870 he began as a transitman working for the city of Somerville, and he continued in the service of that city until 1887, rising from the position of transitman to that of city engineer in 1876. During his long term of residence in Somerville, he served the city on its board of health from 1880 to 1887, on the

CORRECTION

In the July number of the JOURNAL, page 60 (memoir of George A. Kimball), it was incorrectly stated that in 1870 he began working for the City of Somerville. He remained with the firm of Frost Brothers until 1873, when he was admitted to partnership with them.

In 1874 he opened an office of his own as a Civil Engineer in Somerville, and continued it until his election as City Engineer in 1876.

George Albert Kimball.

water board from 1891 to 1900, and as a member of the board of aldermen from 1888 to 1889.

In 1888 Mr. Kimball was made a member of the Massachusetts Grade Crossing Commission, and in 1896 he was appointed by Governor Roger Wolcott as a member of the Metropolitan Sewerage Commission at the time when that commission was constructing its great system both north and south of Boston. He continued on this commission until 1901.

In 1896 Mr. Kimball was made chief engineer of the Boston Elevated Railway Company, which position he continued to hold until his sudden death in 1912. It was in this last position, perhaps, that Mr. Kimball became best known in his profession, and to which he gave the crowning efforts of his life. It was always his aim to secure the very best and most effective in the engineering line, both in the methods used and in the construction itself, of every piece of work over which he had charge. He was not too closely bound by precedent, yet followed what was known to be the best practice.

Conservative in his judgment, he embodied, so far as he felt had been confirmed by theory and experience, any new idea or method to improve new work over that which had preceded it.

There was probably no one piece of construction or achievement in which he had more pride than the newly completed Cambridge Main Street subway. To this work he gave the closest and most careful attention, and it stands to-day a monument to his ability and thoroughness, both in construction, convenience and appointments.

A portion of the year 1902, the year following a severe illness, Mr. Kimball spent abroad in travel through Europe and Great Britain, and during this trip he gained both knowledge and inspiration from his studies of the different types of rapid transit systems in the various countries which he visited.

In 1911 Mr. Kimball attended the excursion of the American Society of Civil Engineers to Panama, having charge of the Eastern party which left New York to inspect the work on the Panama Canal. He published, in conjunction with Mr. George G. Anderson, who had charge of the party of engineers from the West, a very interesting pamphlet giving numerous views of the work as it existed at that time.

The great number of his friends in every walk of life bear testimony to the high esteem in which Mr. Kimball was held. His unfailing courtesy, fair dealing and kindness, together with the remarkable control of himself under the most trying condi-

tions, made of him a man fitted to carry through the difficult tasks set for him to do. He was never hasty in reaching conclusions. His judicial temperament led him to listen patiently to all available testimony and to weigh conflicting opinions with great care. He was quick to sift the important from irrelevant circumstances and to give proper weight to the essential. His unfailing sense of humor smoothed over any bitterness between disputants, and his habit of introducing conferences on delicate questions by boldly attacking and laying bare the heart of the trouble, and then searching for the redeeming features, always left everybody in good humor. Though not much given to public speaking, he was a faithful member of the organizations to which he belonged, and when he took part in discussions, his contributions were always valuable. He was a clear-headed, careful witness in expert cases, and his testimony carried conviction to all who heard it. His loss will long be felt, and his acquaintance remembered by those who were associated with him in his work, as well as by his fellow-members in the various societies and institutions of which he was a member.

Mr.Kimball was married, in 1872, to Miss Lizzie E. Robbins, who survives him. They had four children, Herbert L. Kimball, Mrs. Josephine K. Woodbridge, Ernest R. Kimball and Elizabeth Kimball.

At the time of Mr. Kimball's death he was a director in the American Society of Civil Engineers, and a member of the following engineering societies: Institution of Civil Engineers, American Institute of Consulting Engineers, Boston Society of Civil Engineers, New England Water Works Association, Street Railway Club.

He was also a member of the following fraternal or social organizations: John Abbott Lodge of Masons, Knights of Honor, Royal Arcanum, Winchester Country Club, Engineers Club of Boston.

Mr. Kimball joined the Boston Society of Civil Engineers April 28, 1875, and was its president from March 19, 1902, to March 18, 1903.

J. R. Worcester,
J. W. Rollins,
C. T. Fernald,
Committee.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

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This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

ANNUAL ADDRESS.

BY ROBERT A. MCARTHUR, PRESIDENT OF THE MONTANA SOCIETY OF ENGINEERS.

[Read before the Society at Butte, Mont., April 12, 1913.]

FOLLOWING the customary practice, and in accordance with the mandate of our constitution, I submit the following review of the condition of our Society, and also a summary of the engineering progress and development in the state for the year 1912.

The twenty-fifth annual meeting of the Society was held in April of last year at Anaconda, in accordance with a change in our constitution, making the annual meeting in April instead of January, which had been in vogue since the organization of the Society.

I believe all of us, and especially those who have attended annual meetings for many years past, will agree that the change was wise and will mean, generally speaking, a better attendance at these meetings than was customary in the olden days, when many members were forced to remain at their homes on account of the severity of the weather and the consequent delays in transportation.

A most important feature in the welfare of the Society for the past year was a change in the headquarters, a matter which has been under consideration for many years past by the officers and trustees of the Society. The change from a small, stuffy room, without sufficient ventilation or light, to our present quarters, was a most welcome one, and we as a society are indebted to the county commissioners for permitting us to occupy these rooms under a very reasonable rental.

Some expense was incurred in the purchase of floor rugs and additional bookcases, and the officers feel that we now have a meeting-place suitable to our needs, and hope it will tend to improve attendance at our monthly meetings, and that the rooms will be used at any time by those of our members who wish to avail themselves of the privileges of our library and the current engineering literature.

The reports of the Secretary and the Treasurer, read at the morning session, are fresh in your minds, and it is unnecessary for me to repeat or elaborate upon them at this time.

We may all feel proud of the progress and development of our state for the year 1912. From every source comes the word of steady progress forward in all lines; — the miner, the farmer, the merchant, the railroad builder, and the laborer in all vocations reaping the benefit of prosperous conditions due to a higher price for our copper and silver, an abundant harvest and a year probably unequaled heretofore in railroad activity.

Following the buildings of the railways came a host of settlers upon the public domain adjacent thereto, the building up of many towns and thriving cities and the creation of so many new counties that the map of our state is subject to almost daily change to keep pace with them.

The population of the state made a great increase, particularly in the eastern half of the state, brought about by the railroad building heretofore mentioned; and from a compilation of the data furnished me by the officers of the various United States Land Offices in the state, I find that during the year 1912 there were approximately 15 000 homestead entries filed, covering an area of 2 000 000 acres.

The State Land Department sold, during the year 1912, a total of 210 210 acres at an average of $16.10 per acre.

Good Roads.

The good roads movement made steady progress in our state during 1912. The third annual meeting of the Montana Good Roads Congress, held at Anaconda in July of last year, proved a most successful one; many papers were read and interesting discussions followed, while various excursions over the limestone covered roads of Deer Lodge County added much to the enjoyment of the occasion.

The novel sight of a good road actually under construction within the confines of Silver Bow County was observed with some astonishment, and it may here be mentioned that, at one of the

monthly meetings during the past year, Mr. Oscar Rohn, the man in direct charge of the building of this road, gave us a most interesting address upon the work, which was followed by a general discussion by all members present. In obedience to a general demand, the recent Legislative Assembly enacted a new highway law, providing for a state highway commission, and it is a pleasure to us as members of this Society to know that under the provisions of this law one of our members, a man well-fitted by education and experience, Professor Kneale, of Bozeman, becomes a member of the commission.

The writer has had occasion to travel over many hundreds of miles of roads traversing many of our counties in the western part of the state during the past year, and it was evident that the movement for better highways, both as to construction and maintenance, was making headway, although on several stretches he was forcibly reminded that he was somewhat ahead of the movement.

In our own county of Silver Bow, the building of twenty miles of good road, extending from the city limits of Butte to the west boundary of the county, has been such an object lesson to our citizens that the demand for the continuation of this work, until every road in the county is put into a similar condition, is unanimous, and with the hearty coöperation of our present board of county commissioners, this will, no doubt, be pushed to an early completion.

The work on the roads of the state by prison labor under the direction of the State Board of Prison Commissioners has been continued during 1912, and has resulted in roads being built in some counties which would not have been constructed under ordinary conditions, owing to the heavy expense which would have been involved to counties not financially able to undertake such expenditures.

Stretches of road in Sanders County, on what ultimately will be a main highway from Missoula to Spokane, were built in 1912, and work is still being continued. Work upon the road leading from Livingston to Gardiner, the northern entrance to the Yellowstone National Park, was commenced in 1912 and is still being prosecuted, and consists of rebuilding portions of the existing road, widening at dangerous points, and the elimination of excessive grades.

Mr. Frank Conley informs me that up to this time one hundred miles of road have been constructed by prison labor, at about one third of the cost of free labor.

In the field of municipal engineering several of the cities in the state report progress in street paving and the building of sanitary sewers, while the old wooden sidewalk is fast disappearing from even our smallest towns and the concrete walk is taking its place. The city of Missoula constructed its first street pavement, on Higgins Avenue, extending for about seven blocks and being a brick pavement upon a concrete base.

Mr. P. A. Gow, city engineer of Butte, reports 12 358 sq. yd. of brick pavement laid at a cost of $4.70 per sq. yd., and the construction of 45 540 linear ft., or approximately 8.6 miles, of concrete sidewalk at a cost of $1.45 per sq. yd. for walk and 45 cents per linear ft. for curbing.

There was also 853 linear ft. of reinforced concrete storm sewer constructed, being 3 ft. by 4½ ft. in the clear, at a cost of $8.07 per linear ft.

Northern Pacific Railway Company.

Mr. F. J. Taylor, division engineer Northern Pacific Railway Company at Livingston, furnishes the following account of the work in his department for 1912.

There has not been much work done which could be considered of engineering interest. There were no branch lines built in the state during the year, the work done consisting entirely of improvements on the main line.

In addition to numerous buildings which have been constructed, the work includes the building of 300 ft. of steel and concrete bridges, 450 ft. of concrete culverts, and 2 700 linear ft. of concrete and iron pipe culverts, replacing temporary wooden structures. Ballasting was also done for ninety miles of track, and seventy miles of track were relaid with 90-lb. rail.

Great Northern Railway Company.

One of the largest undertakings on which this company has been engaged was commenced last year, the building of an alternative main line from New Rockford, in the easterly part of North Dakota, west through that state and through Dawson and Fergus counties, Montana, to Lewistown, a total distance of 557 miles. Surveys for this line were completed early last spring and active construction work was commenced during the summer. This line crosses into Montana at Fairview, from which point a connection has been built to the main line at Snowden, necessitating the construction of a steel bridge 1 200

ft. long, built on concrete piers incased in steel shells, at an approximate cost of $500 000. This bridge is interesting from the fact that a straight-lift span will be used over the channel, to take care of navigation on the river. It is the first bridge of its type to be built in the state of Montana.

The entire line from New Rockford to Lewistown will cost approximately $25 000 000, and will probably not be completed for about two years.

During the past season a branch line forty miles in length was constructed and put in operation between Vaughn, a station on our Shelby line just north of Great Falls, west to Gilman, serving a rich country in the Sun River Valley.

A line was also built from Moccasin, a station between Great Falls and Billings, easterly to Lewistown, a distance of thirty miles. This line was built at a cost of $1 000 000 and involved the bridging of the Judith River with a steel bridge 1 900 ft. long and 120 ft. high. At the terminus, Lewistown, an up-to-date brick passenger depot is now being built.

At Highgate, near the summit of the Rocky Mountains, five concrete snow sheds of the latest design, aggregating a total length of 1 450 ft., were built, making safe the operation of trains over one of the most difficult stretches of line in the state.

During the past year the Great Northern Railway has spent a large sum of money opening up and making accessible Montana's newest playground, Glacier National Park, the company having built at Glacier Park station the largest log hotel in the United States and in addition having established accommodations for travelers at several points in the park. Automobile roads and telephone lines have been built connecting these various camping sites.

Chicago, Milwaukee & St. Paul Railway Company.

The largest and most important work inaugurated during 1912 is, undoubtedly, the line now under construction between Lewistown and Great Falls. Preliminary surveys for this line were begun in 1910, and discontinued in the fall of that year. The surveys were resumed in the fall of 1911 and carried to completion during the following winter. Construction began early in 1912, and of the 6 000 000 cu. yd. of grading required to prepare the roadbed, approximately 2 000 000 cu. yd. were moved before the close of the year. Following are the principal characteristics of this line:

Distance, Lewistown to Great Falls	137 miles.
Rock and earthwork to be moved in grading of roadbed	6 000 000 cu. yd.
6 tunnels; aggregate length	4 980 ft.
5 steel viaducts; ranging in height from 135 ft. to 200 ft.; aggregate length	5 275 ft.
Steel bridge across Missouri River at Great Falls; 16 spans; length	981 ft.

As the trend of the drainage between Lewistown and Great Falls is north and south, some very heavy work was done to secure the ruling grade, which is 1 per cent. in both directions, with the exception of 11 miles of 1.5 per cent. pusher grade, eastbound. The longest of the steel viaducts is at the crossing of the Judith River, the distance between abutments being about 1 950 ft. The type of construction is uniform for the five viaducts,—steel towers on reinforced concrete pedestals (4 pedestals for each tower), the tower span being 46 ft., and the span between towers being 70 ft. The spans are plate girders, a ballast deck of concrete slabs being carried on the upper chord. At Cottonwood Creek, about twelve miles out of Lewistown, the "Milwaukee" and the Great Northern Railway have joined in the construction of a temporary timber trestle, single tracks type, the two companies having independent tracks over same, arranged "gauntlet" fashion. Later this is to be filled to provide a double-track roadbed, and will require approximately 375 000 cu. yd. of earth.

A line from Lewistown east to Grass Range, on which the grading of the first 24 miles was partly done about three years ago, was completed last year with regard to grading necessary for roadbed, and an additional 12 miles graded, to reach Grass Range.

During the past year surveys were completed, and contracts let, for an extension of the Lewistown-Roy Line from Hilger to Roy, 26 miles; also for a 22-mile branch from Hilger known as the "Dog Creek Line." Contract was let and work begun on what is called the "Chouteau Line," from Great Falls west up the Sun River and northerly to Agawam, a distance of 65 miles.

The work on all of the foregoing lines is in charge of Mr. A. G. Baker, division engineer, whose headquarters are at Lewistown.

From the time train service was inaugurated west of Butte to date, the "Milwaukee" has been operating its trains over about 15 miles of the main line of the Butte, Anaconda & Pacific Railway from Butte to a point about a mile west of Durant.

Early last year the "Milwaukee" began the work of building its own line so as to be in a position to operate independently of the Butte, Anaconda & Pacific trains. The limits of this new work are Colorado Junction, near Butte, and Cliff Junction, just west of Durant. For a distance of 9 miles, from Colorado Junction west to the mouth of Silver Bow Canyon, the new line will be parallel to and 15 ft. south of the Butte, Anaconda & Pacific Railway main track. At the entrance to the canyon, the new line passes under the Butte, Anaconda & Pacific Railway and the remaining 6 miles consist of heavy rock work along the north side of the canyon. The grading of the 6 miles in the canyon amounts to approximately 300 000 cu. yd. of material, mostly solid rock; the 9 miles paralleling the Butte, Anaconda & Pacific Railway amount to about 130 000 cu. yd. of grading. It is thought that this line will be ready to operate in the latter part of next June. Mr. B. H. Sprague, assistant engineer, is in charge of the above work.

During the year 1912 the Gallatin Valley Railway Company completed a 27-mile branch line extending from Bozeman north to Minard, a point on Dry Creek. This line is now in service and a considerable portion of the Gallatin Valley wheat crop of last year has been handled over it.

The work inaugurated in the year 1912, with respect to new lines, may be summarized as follows:

Lewistown to Great Falls	137 miles.
Lewistown to Grass Range Extension	12 miles.
Hilger to Roy Extension	26 miles.
Hilger north (Dog Creek Line)	22 miles.
Great Falls to Agawam (Chouteau Line)	65 miles.
Colorado Junction to Cliff Junction	15 miles.
Bozeman to Minard (G. V. Ry.)	27 miles.
Total	304 miles.

The following outline will cover the more important engineering works which have been completed during the past year along the operated lines of the "Milwaukee" in Montana:

Mechanical coaling stations, to replace temporary coal docks have been built at Miles City, Melstone, Roundup, Harlowton, Sixteen, Three Forks and Deer Lodge. These seven coaling plants, whose purpose is the delivery of fuel coal to locomotives, are calculated to divide the cost of handling fuel by five, and represent but one of the large number of steps which must be taken to develop the operating facilities of a new rail-

road, which, in its initial stages, must depend upon many a make-shift. These seven coaling stations represent an expenditure of approximately $100 000.

During the past year fifteen timber, or pile, bridges in Montana have been replaced by permanent structures, such as concrete culverts covered with earth embankment, or plate girders on concrete abutments and piers.

Extensions were built on shops and roundhouses at Miles City and Deer Lodge, practically doubling the shop capacity at both places.

At Miles City two 300 000-gal. capacity settling basins were built of reinforced concrete for the purpose of clearing water for use in locomotives and shops.

At Paragon, 8 miles west of Miles City, a 3½ mile spur track has been built to open up a gravel pit from which gravel is to be taken to ballast some 300 miles of main line track.

In Sixteen Mile Canyon between Lombard and Sixteen the channel of Sixteen Mile Creek was changed at three points, eliminating three small bridges from the main line.

The members who attended the last annual meeting, held in Anaconda, will recall with interest our visit to the Washoe Reduction Works and will remember that a portion of the concentrator was undergoing some changes with a view towards higher savings of mineral values. In this connection Mr. E. P. Mathewson's letter relative thereto is of interest. He gives the following as the work of engineering interest performed during the year:

"*First.* We remodeled Section No. 1 of our concentrator, with a view to making lower-grade tailings, and thus increase our savings. This remodeled plant was put in operation in October and has proved fully equal to our expectations.

"*Second.* We have conducted an interesting series of tests on leaching tailings and concentration of slimes, and determined a program for 1913 for further tests on a larger scale; — the preliminary tests gave very encouraging results.

"*Third.* We have erected a coke storage bridge and unloading system, using belt conveyors in our blast-furnace plant."

At the East Helena plant of the American Smelting and Refining Company, Mr. F. M. Smith, manager, reports the following improvements during 1912:

1. Enlargement of the machine shop and installation of the following power tools:

One new style, double spindle lathe, 20 ft. bed, 26 in. and 48 in. swing.

One hand-power hydraulic wheel press.

One belt-driven cold metal saw.

One belt-driven punch and shear, 36 in. throat.

One electric-driven air hammer.

One radial drill.

One sensitive drill.

2. Improvements in ventilating system of blast-furnace building, including installation of special hoods over slag and matte spouts, and over slag pots, all being connected with a Sirocco 40-in. exhaust fan, for the purpose of carrying off the smoke and fume from the blast furnaces.

3. Construction of a 200-ft. section of brick flue, connecting our four large Dwight sintering machines with the Huntington & Heberlein flue system, thereby enabling us to discharge the Dwight machine gases into our highest roaster stack.

4. Construction of a lead drossing plant for drossing lead bullion before shipment to the refinery. This plant consists of four 50-ton cast-iron drossing kettles, two electric hoists for elevating the hot lead to the kettles, so arranged that the drossed bullion may be drawn off by gravity into molds, the entire plant being housed in a steel building about 44 ft. wide by 126 ft. long.

5. Installation of a Crocker-Wheeler three-bearing motor generator set, consisting of a 150 h.p. induction motor, coupled to a size 125 H, interpole, 100 kw., 500 volts, direct-current generator.

6. Installation of a No. 8 Roots rotary pressure blower; approximate capacity, 11 500 cu. ft. of air per minute at 42 oz. pressure; driven by a 150 h.p. motor.

7. Construction of a bath house for the men in the plant, with sinks and shower baths; hot and cold water.

Anaconda Copper Mining Company, Boston & Montana Reduction Department, Great Falls, Montana.

At the Boston & Montana Reduction Works of the Anaconda Copper Mining Company, at Great Falls, construction during the year 1912 has been comparatively little, but plans have been made for the complete remodeling of the smelting plant, and considerable material ordered and received, and some erected.

A great deal of experimenting has been done during this year, and previous years, to determine processes and appliances

which could be used in the new plant. One of the chief experiments for the year 1912 was in the converting department. During the preceding years four different sizes of converters, each larger than the preceding, have been tried, all of the upright type. The largest of these, called the "Class 4," was 12 ft. in diameter. In the year 1912 a converter 20 ft. in diameter was built and put into service, and has proved very satisfactory and will be adopted as the standard converter of the new plant. It has resulted in a greatly increased production from a single unit, with a corresponding reduction in the labor employed and with no reduction in the efficiency of air used. The necessary pressure for operating has been reduced by proper design and connection of tuyères, with a consequent saving in the cost of operation. There is probably no reason why a larger converter could not be built and operated, but this size seems to be about the practical limit because larger units would be too large for any ordinary plant to supply with material.

In the new plant the reverberatory furnaces will be of a different type from those in the old plant. In the old plant they were gas fired regenerative furnaces, with hearths 45 ft. long by 15 ft. 9 in. wide. The new furnaces will have hearths 102 ft. long by 22 ft. wide. They are called direct-fired furnaces, but strictly the fire box which is directly on the end of the furnace will be a very large producer, with specially designed grates and apparatus for manipulation, forced draft will be used, and if any steam is required to soften the clinker, this will be introduced under the grates. The waste gases will pass through hot blast stoves for regenerative purposes, and also through boilers to absorb any waste heat not otherwise used. The furnaces will thus be regenerative.

The new plant will contain a thawing shed, for the thawing out of ores and other raw materials in freezing weather. The immediate heating of the thawing room will be by hot air, which will be heated by steam from the waste heat reverberatory boilers.

The disposition of slag from the smelting furnaces will be by means of 30-ton slag pots, which will receive the slag directly from the furnaces and carry it to a slag dump in a large coulee east of the plant, thus removing it from the Missouri River, where it has previously been disposed of.

The year 1912 in the electrical field was one of steady advancement, the important features being the gradual extension of high-power transmission lines radiating from the various

power plants in the state, the beginning of the work of electrifying the Butte, Anaconda & Pacific Railway, and the construction of the first large electric pumping plant for irrigation.

The official announcement of the electrification of the Chicago, Milwaukee & St. Paul Railway from Harlowton, Mont., to Avery, Ida., covering 450 miles, was an event of national importance in the ever-widening field of electrical engineering.

Mr. Max Hebgen, vice-president and manager of the Montana Power Company, has furnished the following as the important work performed by the various companies under his supervision during the year 1912.

Montana Reservoir & Irrigation Company.

This company has continued work on its dam in the Upper Madison Canyon, and the dam now stands at an elevation 45 ft. above the river bed. The dam will probably be completed in another season, and will form a reservoir having a capacity of 15 000 000 000 cu. ft.

The company has also constructed its first pumping plant on the Prickly Pear Project, near Helena. This plant pumps water from Hauserlake and requires 1 800 h.p. for its operation. There are at present installed 3 pumping units, each unit consisting of 3 centrifugal pumps all mounted on the same shaft and direct-connected to a 600 h.p. motor. This plant will supply water for 5 000 acres of land. Electric power will be supplied from the plants at Hauserlake and Canyon Ferry.

Great Falls Power Company.

This company has constructed transmission lines from Great Falls to Havre, Lewistown and Cascade. The wood-pole type of construction was used with suspension insulators, and the lines are designed to operate at 88 000 volts. Substations have been installed at the terminal points mentioned and also at Fort Benton, Big Sandy, Moccasin, Belt, Sand Coulee and Stockett. About 1 200 kw. is being delivered to the latter point for the operation of the Cottonwood Coal Company's coal mine.

Northwestern Development Company.

This company has built a 750 kw. hydro-electric plant at the mouth of Prospect Creek near Thompson Falls. The plant takes its water from Prospect Creek through a 48-in. wood stave pipe about 8 000 ft. long and under a head of 180 ft. A 60 000

volt pole line has been constructed from this plant to the town of Paradise, where it connects with the Iron Mountain Tunnel Company's line from its mine at Iron Mountain. About 500 kw. will be delivered to this mine, and in addition to this it is expected that power will be supplied for lighting and miscellaneous purposes at Paradise, Plains and Thompson Falls.

In response to my inquiry, Mr. F. W. C. Whyte, in charge of the Coal Department of the Anaconda Copper Mining Company, furnished the following summary of the coal industry for 1912.

"The year 1912 was comparatively a normal year in the coal mining industry in Montana. The output for the year was slightly over 3 000 000 tons, a very slight increase compared with the year 1911. No new camps were opened up during the year, but in some instances new mines were opened up at some of the existing camps. The most important of these are in the Bear Creek field, where two of the companies operating there have opened up new mines adjacent to the old ones. The only interesting feature from an engineering standpoint is the introduction of electric power at the coal mines in the Stockett and Sand Coulee field. The Cottonwood Coal Company at Stockett changed its air compressors from steam to electric, buying its power from the Great Falls Power Company, so that its mining nachines and drills are now being run by electric power in the form of compressed air. Other mines in the same field, which did not have power plants installed, are equipping with electric coal punchers and drills, using the power direct."

United States Reclamation Service.

The Milk River project and the St. Mary Storage feature thereof, and the Sun River project, are being put under construction in a relatively large way. A total of seven million dollars has been allotted to these two principal projects and feature. Contracts have been awarded for the several large main canals throughout the Milk River Valley, and the construction of Vandalia Diversion Dam above Glasgow has been authorized with government forces. Twenty-five thousand acres in the vicinity of Chinook, under private canals, but with an insufficient supply of water, will receive an abundant supply of water from the St. Mary Storage Work. The canals projected for immediate construction by the Reclamation Service will deliver water to 25 000 acres of land in the vicinity of Malta and 25 000 acres in the vicinity of Glasgow. Proposals for structures and distribution system; complete, will be advertised for in the near future.

Proposals for constructing the St. Mary Canal, which will have a capacity of 1 700 acre-ft. per day, and a total length

Department of the Interior, United States Reclamation Service, Northern Division.

Reclamation Service Projects in Montana.

Projects.	Estimated Total Irrigable Area. (Acres.)	Areas for which Irrigation w'ks have been Completed. (Acres.)	Area Irrigated, Season 1912. (Acres.)	Total Expenditures to Oct. 31, 1912.	†Estimated Total Cost of Project.
Huntley	32 405	28 805	14 423	$1 171 836.13	$1 156 000.00
Lower Yellowstone	60 246	37 609	5 068	3 152 541.75	3 231 000.00
Milk River (*a*)	219 557	7 800	359	1 157 830.52	7 740 000.00
Sun River (*c*)	322 000	16 346	6 824	(*b*) 992 105.46	(*c*) 8,960 000.00
Totals, Reclamation Service	634 208	90 560	26 674	$6 474 313.86	$21 087 000.00
Indian Service Projects in Montana.					
Blackfeet	122 500	26 644	0	$718 805.82	$3 000 000.00
Flathead	152 000	32 000	4 217	1 123 684.72	6 243 489.04
Fort Beck	152 000	2 500	0	(*b*) 209 673.83	5 169 300.00
Totals, Indian Service	426 500	61 144	4 217	$2 052 164.37	$14,412 789.04
Totals, Montana	1 060 708	151 704	30 891	$8 526 478.23	$35 499 789.04
Other Reclamation Projects.					
Shoshone, Wyoming	164 122	41 322	15 297	$4 087 168.37	$7 828 000.00
North Dakota Pumping, No. Dak.	*26 182	12 107	323	925 831.01	1 439 000.00
Totals, Other Projects	190 304	53 429	15 620	$5 012 999.38	$9 267 000.00
Grand Totals, Northern Div.	1 251 012	205 133	46 511	$13 539 477.61	$44 766 789.04

* Buford-Trenton sub-project, 15 035 acres; Williston sub-project, 11 147 acres.
† Preliminary estimate subject to material change after construction.
(*a*) Includes St. Mary Storage. (*b*) Total expenditure to Sept. 30, 1912. (*c*) Estimated expenditure for project of 200 000 acres.

of 29 miles, will be received April 28. Seven miles of the canal have already been constructed in part by government forces. The St. Mary Lakes will be reservoired, also the Sherburne Lakes and the McDermott Lakes, the two latter in Glacier National Park.

Proposals for excavating the main canal of the Sun River project will probably be received about the first ot May. This canal is projected for an ultimate capacity of 5 000 acre-ft. per day and will be constructed half size for first development. The portion to be advertised for will have a length of about 45 miles. The Sun River Diversion Dam has been authorized for construction by government forces. This will have a total height of 145 ft., and will act as a diversion dam only. A storage reservoir will be constructed after a few years at the junction of the principal forks of the Sun River, ten miles above the diversion dam. Contract has been executed with the Great Falls Power Company for the delivery of electrical energy for excavating the canals and driving the tunnels, of which there will be two, having a total length of about three quarters of a mile, and for all power requirements in connection with government force work and the contract work. The Power Company has contracted to construct upwards of one hundred miles of trunk transmission line, extending to the Sun River Diversion Dam and north across the project to the Teton River. The Reclamation Service is now installing 45 miles of distribution transmission line along the first canal and for the tunnel and diversion dam work. The Reclamation Service is now using electrically actuated drag-line scrappers and "steam" shovels with marked economy and satisfaction.

In the Butte District, the past year was one of steady progress in the mines, there being, however, no new work of especial engineering interest, but only a continuation of improvements previously inaugurated. The development of the zinc ore-bodies in the properties of the Butte & Superior Copper Company and W. A. Clark have proven of such magnitude that the former company erected a concentrating mill of 500 tons daily capacity, while the latter has acquired a site and is now at work upon a mill for treating the zinc ores already developed in his properties.

The Butte Central Copper Company has but recently completed a mill for treating the ores of the Ophir mine, having a daily capacity of 200 tons.

The Bulwhacker Mining Company and the Butte & Duluth Copper Company, owning adjoining properties in the south-

eastern part of the district, both erected experimental plants for treatment of the copper ores found in their properties, these ores being different in character from the ores hitherto found in the other developed mines of this district.

The year 1912 has been an active one with the Anaconda Copper Mining Company. The average number of men employed per day was from 9 000 to 9 500. The ore shipped to the reduction plants at Anaconda and Great Falls showed a marked increase over the preceding year.

During the year five shafts have reached the level of the 2 800 of the High Ore, viz., the Anaconda, St. Lawrence, West Steward, Original and Tramway. With the exception of the Anaconda mine, none has yet been connected with the High Ore shaft, although work is progressing with that end in view, as the 2 800 is to be the drain level, and the main pumping plants are located at the Lenord and High Ore shafts.

During the year four of the main hoisting engines have been equipped to run with compressed air, viz., Original, Tramway, Pennsylvania and Leonard; also the auxiliary engines at the Green Mountain, Diamond and Tramway mines.

The original installation at the compressor room for furnishing air for the hoisting engines consisted of 3 Nordberg compressors, 30 in. and 50 in. by 48 in., with a capacity of 7 500 cu. ft. of air each per minute, aggregating 22 500 cu. ft. per minute. During the year three additional compressors of equal capacity have been added to the plant, making a total of 45 000 cu. ft. of air per minute, compressed to 90 lb.

The number of electric motors is increasing from year to year; there are at present over 50 motors underground, used for hauling the ore from the stopes to the shafts, and between 15 and 20 on the surface, in the lumber yards and at the ore bins.

Every main cross-cut or drift is laid out with the probability that sooner or later a trolley wire and motor will be installed, and ample room is allowed, and an extra heavy T rail is used for the track.

The motors have been found so satisfactory for underground work that they are rapidly replacing all other methods of transporting ore, waste or timber.

The foregoing comprises the "summary of engineering progress during the preceding year," as provided for in our constitution, and while I realize that it has fallen far short of covering the field, I can only plead in extenuation that the framers

of our constitution twenty-six years ago did not comprehend or even grasp the undertaking they had assigned to the retiring president at this day. Then, again, it is the privilege of the present day and age, for want of better argument, to lay the blame for our troubles on those who laid the foundations of government, and I shall avail myself of that privilege, feeling as I do that what I have written is a very incomplete summary of engineering progress in Montana for the year 1912.

Were I to attempt to use all the data I have received, or to have covered the field of engineering by reviewing the work of many achievements not even mentioned by me, the entire time of this afternoon session would be consumed, and the more interesting addresses and discussions to follow would then be lost to us.

To the following gentlemen I wish to acknowledge my gratitude for their courtesy and promptness in furnishing the data used in the preparation of this address:

Mr. R. Budd, chief engineer, Great Northern Railway Company.

Mr. C. A. W. Musson, assistant engineer, Chicago, Milwaukee & St. Paul Railroad.

Mr. F. J. Taylor, division engineer, Northern Pacific Railroad.

C. A. Lemmon, chief engineer, Butte, Anaconda & Pacific Railroad Company.

H. N. Savage, supervising engineer, United States Reclamation Service.

B. H. Dunshee, assistant superintendent of mines, Anaconda Copper Mining Company.

E. P. Mathewson, manager, Washoe Reduction Works.

A. W. Wheeler, superintendent, Boston & Montana Reduction Department, Anaconda Copper Mining Company.

F. W. C. Whyte, manager coal department, Anaconda Copper Mining Company.

Paul A. Gow, city engineer, Butte.

F. M. Smith, manager, East Helena Plant, American Smelting and Refining Company.

I appreciate the honor of having served as President of the Montana Society of Engineers, and wish to thank you all for it. In conclusion, let me express the hope that the membership will give its united support to the new officers in their efforts to upbuild and strengthen the Society, that it may continue to grow and prosper and always be a vital force in the upbuilding and engineering development of our state.

THE INTERCEPTING SEWER SYSTEM OF SYRACUSE, N. Y.

By Glenn D. Holmes,* Member of the American Society of Civil Engineers.

In the short time allotted for the presentation of this paper the writer can but very briefly describe a few of the more interesting features of the design and construction of the Intercepting Sewer System of the city of Syracuse.

Syracuse, the central city of New York, is situated at the head of Onondaga Lake, a body of water having an area of about $4\frac{1}{2}$ square miles, which eventually finds an outlet through the Seneca and Oswego rivers to Lake Ontario. The city, approximately rectangular in outline, includes an area of about 18 square miles. About 80 per cent. of its area is tributary to Onondaga Creek, a stream flowing in a general northerly direction midway between its eastern and western boundaries. The mean monthly discharge of this stream varies between 40 and 425 cu. ft. per sec., giving run-offs of 0.35 and 3.75 cu. ft. per sec. per square mile from its catchment area of 113 square miles. Harbor Brook, a much smaller water course, winds through the western portion of the city after receiving the drainage of about 10 square miles.

Both Onondaga Creek and Harbor Brook, in receiving the discharge from the many outlets of the city's combined system of sewers, became so badly polluted that the most objectionable and unsanitary conditions prevailed along these water courses. The work of abating these nuisances by constructing intercepting sewers, in general paralleling the streams, and by improving the streams themselves by deepening and lining their channels with concrete masonry, is so far advanced that a very material improvement is now apparent.

Syracuse at present has a population of about 145 000, and the water consumption is approximately 90 gallons per capita per day. In the design of the intercepting sewers, provision has been made for a volume of sewage equal to 375 gal. per capita per day, from a population of 400 000. This allows for what we have termed "double sewage," it being assumed that "single sewage," or the maximum amount of actual sewage, will not exceed 125 gal. per capita per day, and further that an excess

* Chief engineer, Syracuse Intercepting Sewer Board.

amount of 50 per cent. will provide for the maximum rate of discharge during any hour of the day.

In the determination of the rate of grade and the elevation of the sewers, we were limited at the outlet by the elevation of Onondaga Lake, and at various points along the route by the elevation of existing lateral sewers underneath which it was necessary to pass. These limitations resulted in sewer sizes varying from 8 ft. to 33 in. for the main intercepting sewer along Onondaga Creek, and for sewers from 54 in. to 18 in. for the Harbor Brook system.

In the determination of the sewer sizes, Kutter's formula was used, n being assumed at 0.013 for concrete. When the sewers are flowing full, the velocities will vary between 3 and 5 ft. per sec.

The larger sizes of the main intercepting sewer have been constructed having a cross-section of modified horseshoe shape, in which the vertical diameter is equal to that of a circular sewer having the same capacity. This section results in a considerable saving of excavation over that required for circular sewers, and a minimum width of trench, which was of especial advantage through the congested streets and where many underground obstructions existed. The contract drawings provided for three alternative forms of construction, — plain concrete, reinforced concrete and reinforced concrete pipe, the latter being limited to sections having a vertical diameter not greater than 56 in. The larger sewers were constructed of plain concrete, the lowest bid for the whole work being lowest for this type of construction. The smaller sizes were constructed of reinforced concrete pipe.

The contract drawings for the Harbor Brook work provided two alternative forms of construction for the sections between 33 and 56 in. in diameter, namely, monolithic reinforced concrete and reinforced concrete pipe; the latter was used in the work. The smaller sewers, 25 in. and 30 in., have plain concrete side walls and invert and a top of reinforced concrete slabs which were cast separately and after seasoning were set in place and grouted. The cross-sections of these smaller sewers are modifications of the design of the sewer department of the city of Boston.

The geological formation throughout the greater portion of the Onondaga Creek and main intercepting sewer district consists of sand and gravel, affording generally a suitable foundation for the sewers and appertaining structures. Some soft clay was encountered, which was stiffened by the addition of

Fig. 1. Main Intercepting Sewer. 90-inch Section. Shallow Trench.

Fig. 2. Main Intercepting Sewer. 64-inch Section. Deep Trench.

broken stone and gravel. Throughout one section of some 1 500 linear ft., quicksand necessitated the construction of a special foundation, where a double row of piling and timber platform were used. The Harbor Brook district is underlaid by a deep stratum of compressible muck, and the larger sewers were supported on a single row of piles. In certain sections where the foundation soil was less yielding, broken stone or gravel was employed to stiffen the soil, and a spread-footing of reinforced concrete was placed to distribute the loads over a greater area.

The method of interception of sewage from the lateral sewers of the main intercepting sewer system is somewhat different from that employed in the Harbor Brook system. In both systems a chamber surmounted by a manhole is constructed on the lateral sewer at the location most suitable for the diversion of the sewage. In the chambers leading to the main intercepting sewer the invert and one side of the lateral sewer are made continuous throughout the chamber. The other side of the sewer is omitted, the invert continuing horizontally to the side and dropping to a pit which is connected to the intercepting sewer by a vitrified pipe. On the lateral sewer, just beyond this chamber, a small dam is constructed with its crest at the elevation required to divert the predetermined volume of double sewage.

In the intercepting chambers of the Harbor Brook system, adjustable openings in the inverts of the lateral sewers are pro-

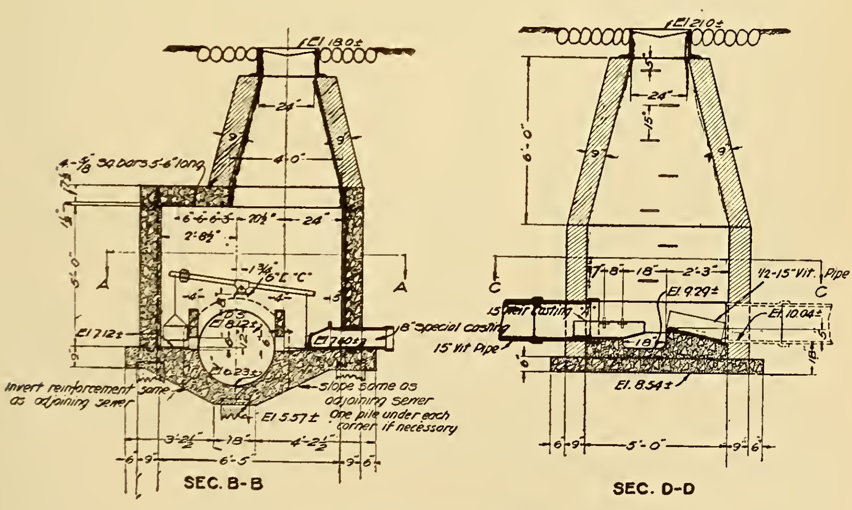


FIG. 3. VALVE CHAMBER AND INTERCEPTING CHAMBER, HARBOR BROOK SYSTEM.

vided, through which the desired volume of sewage may be intercepted. The invert of the sewer approaching this opening in each case is designed to increase somewhat the velocity of flow at the opening and produce a spouting effect in order that the width of opening may be sufficiently large to pass objects which might otherwise become stranded and obstruct an opening of less size. The adjustment is made by means of a movable casting which may be locked in the desired position. For all stages of flow up to a certain volume of discharge, the sewage drops through the opening and is conducted to the intercepting sewer. As the volume of sewage increases above this stage the excess volume leaps the opening and passes to the brook.

The pipe connections from these intercepting chambers terminate at the intercepting sewers in regulating valves. These valves automatically close as the depth of flow in the intercepting sewers approaches a predetermined height and thus prevent the intercepting sewers being placed under a head. This condition might otherwise occur during extreme flood conditions when water from the streams backs up the lateral sewers to the intercepting chambers. The valves, which are located in a small chamber at the side of the sewer, consist of a cast-iron body and pivoted gate, the movement of which is actuated by the rise and fall of a copper float.

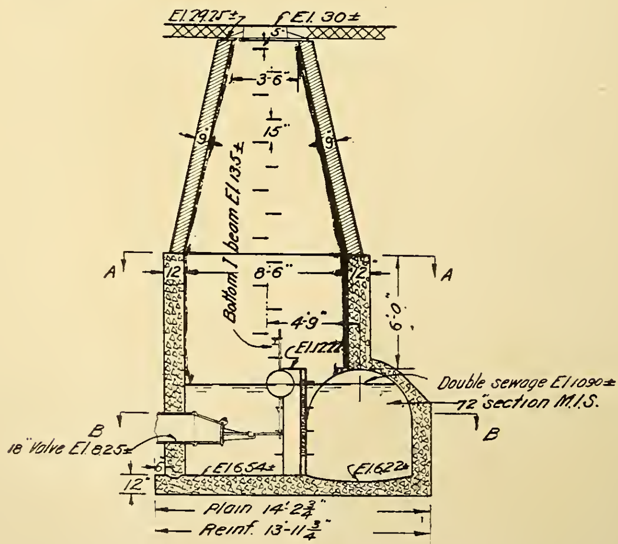


FIG. 4. VALVE CHAMBER, MAIN INTERCEPTING SEWER.

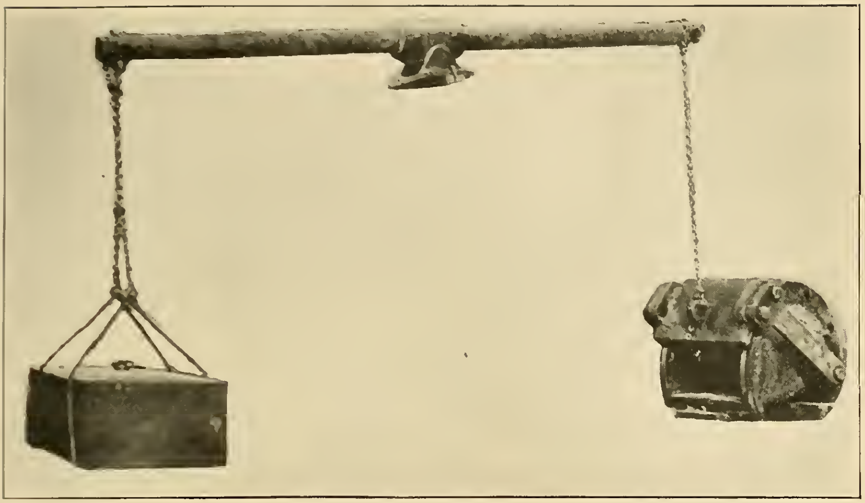


Fig 5. Regulating Valve with Float and Walking Beam connection.
Harbor Brook system.

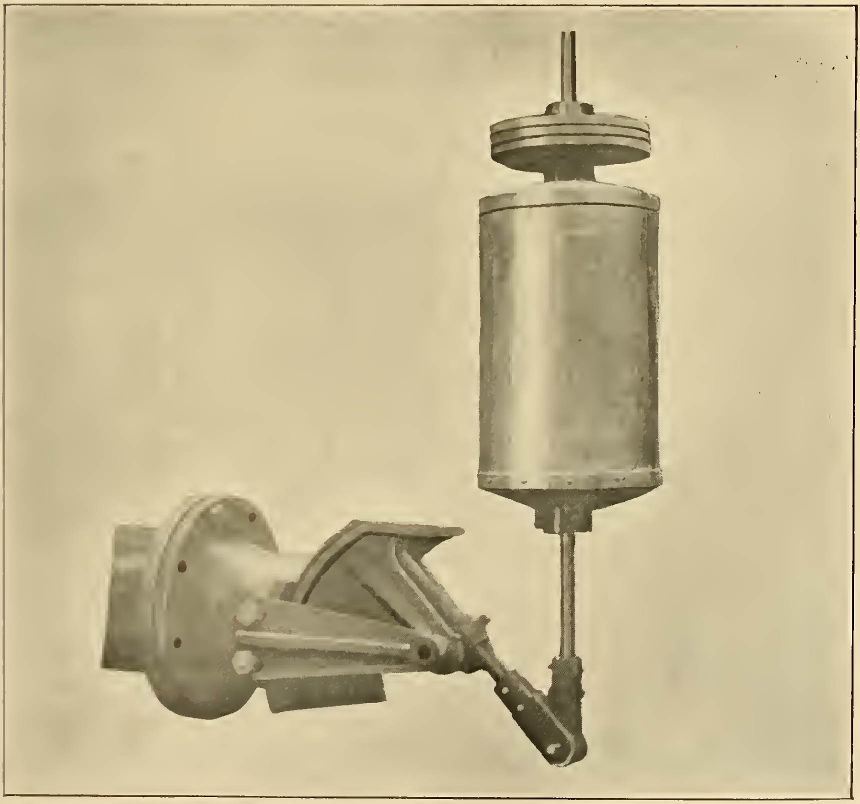


Fig. 6. Regulating Valve. Main Intercepting system.

Fig. 7. Onondaga Creek Improvement, showing Concrete Block Lining, Semi-circular Flume of 10-ft. diam. along left bank carrying flow of Creek around work of construction.

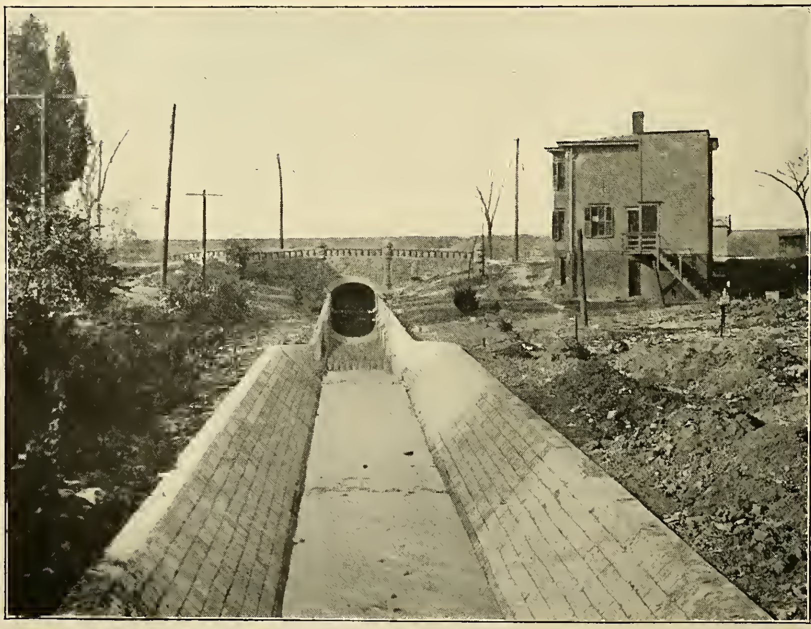


Fig. 8. Harbor Brook as improved.

The relative elevations of the main intercepting sewer and the invert of the improved creek channel are such that inverted siphons are required at various locations to conduct the intercepted sewage across and underneath the creek channel to the intercepting sewer. These pipe crossings consist of duplicate lines of cast-iron pipe surrounded by concrete which terminate in manholes on both sides of the creek channel. Provision is made for cleaning these siphons by flushing with city water under a pressure of some 90 lb., and also by using the ordinary jointed sewer cleaning tools.

Many of the lateral sewers have been constructed at such an elevation that their outlets are below the normal water surface of the streams into which they discharge, and frequently back water reaches the point where interception of the sewage is to be made. The deepening and improvement of the creek channel for the purpose of lowering its water surface is therefore necessary for the efficient operation of the sewer system. The cross-section and grade adopted for the improvement is such as to provide for a run-off of about 6 ft. per sec. per square mile from the drainage area before the water will rise to such height as to interfere with the free discharge of the storm water overflow from the lateral sewers. Discharges in excess of this amount may be classed as abnormal and are so infrequent as to interfere rarely with the operation of the intercepting sewer.

The necessity of protecting the deepened channel with a lining to prevent erosion has been demonstrated by the results of previous attempts to improve the channel; wash drill borings made in the creek bottom indicated that practically all of the deepened channel would be in sand and gravel of various classifications, and, after careful consideration of this feature of the work, concrete in the form of blocks was finally adopted as meeting all of the requirements most satisfactorily. The large volume of ground water to be expected from both bottom and sides of the deepened channel prevented the serious consideration of monolithic concrete. With concrete blocks it is necessary to keep the water pumped down only while the blocks are being placed, and during the laying it is not necessary to keep the water at as low an elevation as would be required with monolithic work. The blocks which are being laid with open joints offer the further advantage of preventing unbalanced water pressure.

The blocks were designed to be of such size and weight as to afford no opportunity for dislodgment after being placed and still be convenient for handling, and so that the men engaged

in laying them might be able to work continuously throughout the day. Blocks for the invert have been made 8 in. by 8 in. by 12 in., and for the side slopes 6 in. by 12 in. by 12 in., weighing about 60 lb. in each case. Two dimensions of the blocks were made of equal length in order to have four similar faces; this facilitates the laying of blocks by permitting any one of the four suitable faces to be placed upwards without rehandling or turning, and offers the further advantage that a less number of blocks need be condemned on account of imperfections, for the reason that an imperfect face or corner may be placed so as not to be exposed in the finished work.

The work of improvement of Harbor Brook is similar to that of Onondaga Creek though on a much smaller scale. Ground-water conditions permitted the laying of a monolithic invert after diverting the flow of the brook to the intercepting sewer which had been constructed in advance.

The construction of the Harbor Brook system, including both the sewer and brook improvement work, is practically completed, as is also the main intercepting sewer through the most densely populated section of the city. Work on the Onondaga Creek improvement is not as far advanced, although some of the most difficult construction work has been accomplished. The general plan along which we are working provides for the collection of all sewage to a single outlet near the lake by gravity, at which point a pumping station is to be installed in connection with sewage treatment works.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 15, 1913, for publication in a subsequent number of the JOURNAL.]

THE FITCHBURG, MASS., INTERCEPTING SEWER.

By David A. Hartwell,* Member of the Boston Society of Civil Engineers.

[Read before the Sanitary Section of the Society, February 5, 1913.]

The city of Fitchburg, Mass., is situated in the valley of the north branch of the Nashua River, where the topography of the land changes from the rolling portion of the eastern part of the state to the more hilly and rugged area of the central part. The eastern part of the city is not so hilly as the central and western portion. In the central and western portion of the city the valley is narrow, varying from about 300 ft. in width to a maximum of about one-half mile. Outside this narrow valley the street grades are steep, 10 per cent. or more being very common, the maximum reaching as high as 25 per cent. The residential portion of the city is spread out on the sides of the hills, and in a number of cases reaches even to the summit. The difference in elevation of land within the corporate limits of the city is over 800 ft. The location of the city was largely determined through the development of the available water power, and this has brought about a city having a total length of manufacturing and residential sections of over 6 miles and no great width at any location. The drainage area of the north branch of the Nashua River at the central part of the city is about 62 square miles. On this drainage area there is a fair amount of storage controlled by the mill owners, which increases to some extent the flow of the river during the drier months of the year. From measurements taken it is possible that the total flow in the river at times does not exceed 12 000 000 gal. per day. The average flow during the summer months is about 30 000 000 gal. per day. Flood conditions are not very frequent at any season, and then only of about two days' duration. As the flow of sewage varies from 4 000 000 gal. to 6 000 000 gal. the dilution is very small. In the flow of the river through its six-mile course in the settled portion of the city, there is a total fall of over 240 ft., practically all of which is used for water power. The flow of the water over the various dams and through the wheels has aërated to some

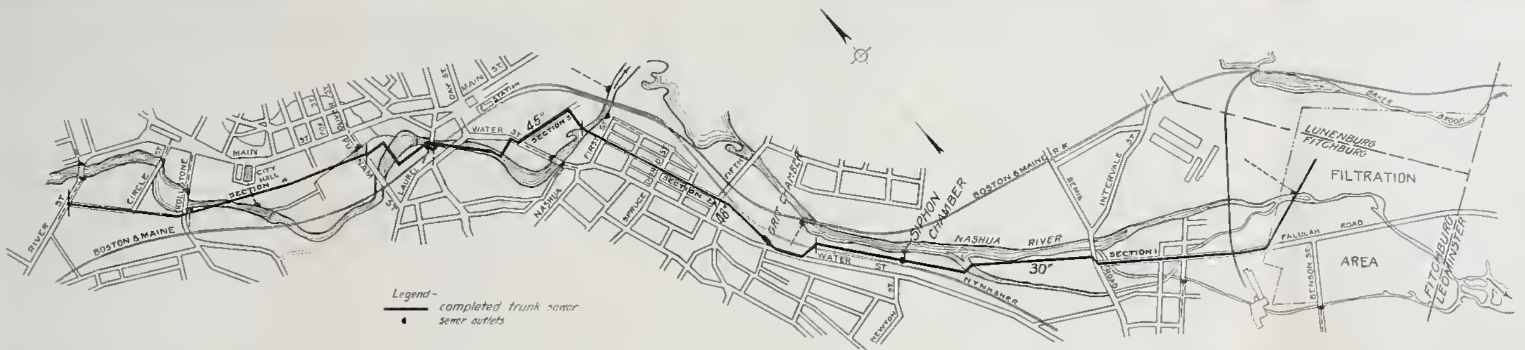
*Chief Engineer Sewage Disposal Commission.

extent the flow and so helped to prevent as great a nuisance as would be expected from the great pollution of the water. Still, during the hot summer weather, when the flow in the river is at the minimum, the odors arising from the river are very objectionable and at times quite noticeable even some distance away. While this pollution is objectionable on account of sight and smell, yet it has been the cause of no disease or sickness so far as I have been able to ascertain.

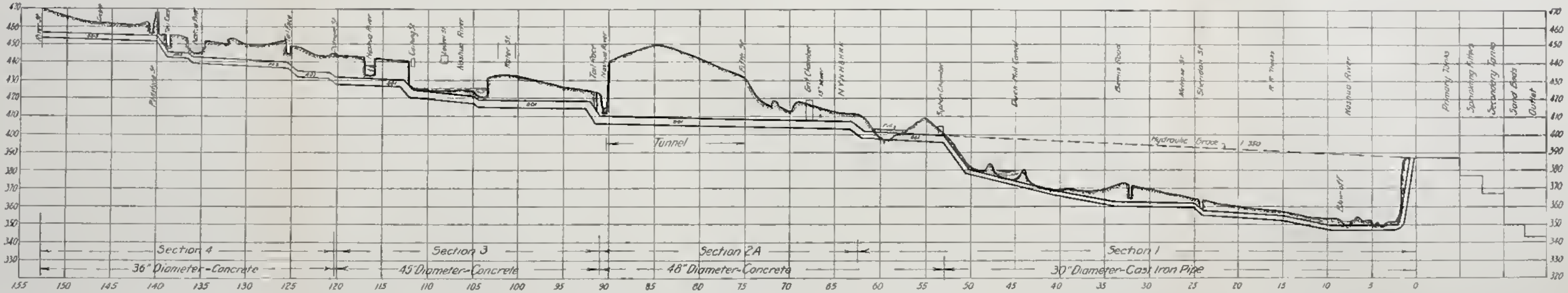
The sewerage system of the city is on the combined plan, there being at present about 44 miles of sewers, varying in size from 8 in. to 60 in. in diameter. These sewers discharge into the river at the most convenient places along its course through the city, there being 27 such outlets, covering a total distance of over five miles. The need of an intercepting sewer in Fitchburg has been admitted for many years, and during my service of twenty years as city engineer three separate studies of this problem were made and reports sent to the city council, the earliest one being in 1895. Legislation authorizing the construction of an intercepting sewer and a disposal plant was enacted in 1910, but for reasons having no special bearing on this paper no attempt was made at construction at that time. A suit against the city by one of the mill owners for pollution of the river was instituted, and considerable preparation was made for trial both by the city and the mill owner. This suit was finally dropped by the plaintiff. The need of an intercepting sewer and some form of sewage disposal has been urged by the state board of health for many years, and as a result of this urgency legislation was enacted in 1910 authorizing the appointment of a special commission to build an intercepting sewer and a disposal plant and so improve the condition of the river. This commission immediately started studies relative to the construction of this intercepter.

In designing the intercepting sewer the aim was so far as it was possible so to design and construct this sewer that it would care for the flow of sewage for at least thirty years, the period of time for which the bonds were to be issued. This not only required the study of the probable total population of the city in 1940, but also the probable location of this population and the manufacturing industries at that time.

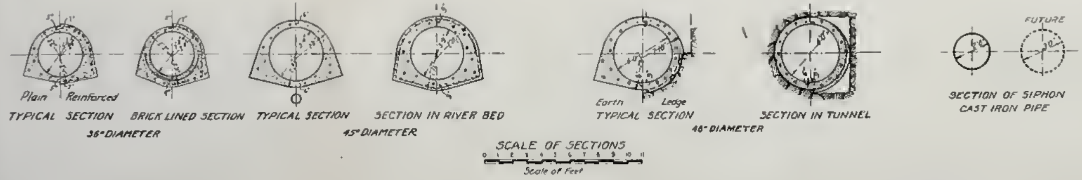
During the thirty-five years preceding the year 1910, Fitchburg had shown a continued increase in population for each five-year census, the smallest percentage of increase being 1.1 per cent. and the largest 43.3 per cent.



PLAN



PROFILE



City of Fitchburg
Sewage Disposal Commission

MAIN INTERCEPTING SEWER-SECTIONS 1, 2A, 3, 4.

PLAN AND PROFILE

SCALES

VERTICAL — SCALE OF FEET

HORIZONTAL — SCALE OF FEET

1913.

Sheet No 2

GROWTH OF FITCHBURG FROM 1875 TO 1910.

Date.	Population.	Per Cent. Increase.
1875	12 289	
1880	12 429	1.1 per cent.
1885	15 375	23.7 per cent.
1890	22 037	43.3 per cent.
1895	26 409	19.9 per cent.
1900	31 531	19.4 per cent.
1905	33 021	4.7 per cent.
1910	37 826	14.6 per cent.

Average rates of increase per period of five years, 18.1 per cent.

The average rate of increase for a five-year period was 18.1 per cent. The rate of increase in population for this period was about an average of the increase in population in ten other Massachusetts cities of about the population of Fitchburg. A study was made of the increase in population of the larger cities in the state of Massachusetts, excepting Boston, since they had the same number of inhabitants that Fitchburg had in 1910, namely 37 826. These cities, ten in number, show an average rate of increase for five-year periods of 18.04 per cent.

RATE OF INCREASE IN POPULATION OF TEN CITIES OF MASSACHUSETTS BOTH BEFORE AND AFTER REACHING THE 1910 POPULATION OF FITCHBURG (37 826), AND THE AVERAGE FOR FIVE-YEAR PERIODS FROM 1865 AND 1875 TO 1910.

	End of Five-Year Period when Nearest Size of Fitchburg.	Average Rate of Increase for a Period of 20 Years before that Date. Per Cent.	Average Rate of Increase after that Date to 1910. Per Cent.	Average of Rates of Increase per Period of 5 Years. Per Cent.	Period of Time.
Worcester	1870	25.0	16.8	19.66	1865–1910
Fall River	1875	39.5	15.1	25.45	1865–1910
Lowell	1870	6.7	12.8	12.61	1865–1910
Cambridge	1870	27.4	13.0	15.58	1865–1910
New Bedford	1890	17.9	24.5	21.1	1875–1910
Lynn	1880	19.4	15.2	15.75	1875–1910
Springfield	1885	14.4	18.8	16.24	1875–1910
Lawrence	1880	22.3	14.3	13.94	1875–1910
Somerville	1890	29.3	18.0	19.95	1875–1910
Holyoke	1895	25.7	12.7	20.16	1875–1910
Average	....	22.8	16.1	18.04	....
Fitchburg	....	14.6	15.0*	....	....

* To 1940.

The past growth of Fitchburg and the local conditions were such as to make it seem probable that Fitchburg would not maintain as great a rate of growth during the next thirty years as it has during the past thirty-five years, or that the rate of growth would probably not be quite equal to the average of the ten larger cities during recent years. It was decided that a reasonable prophecy of the future growth during the period from 1910 to 1940 would not exceed 15 per cent. for each five years. This would give a population in accordance with the following table:

Estimated Future Population of Fitchburg.

(15 per cent. increase each five years.)

Date.	Population.
1910	37 826
1915	43 400
1920	49 800
1925	57 400
1930	66 000
1935	75 800
1940	87 200
1945	100 300
1950	115 000

The next problem was to study the possible distribution of this population of 87 200 as assumed for the year 1940. The distribution of the increase of population and manufacturing in recent years was studied as an aid in prophesying the location of this assumed population. The result was an assumed residential area in 1940 of 6 878 acres and an industrial area of 1 256 acres, the industrial area to be located largely within the river valley and the residential area distributed on the higher land. The distribution of the population of 1910 was studied on the basis of the division of the assumed residential and manufacturing area into 28 districts. This showed a population ranging from 0.3 of one person per acre to a density of 77.7 persons per acre. In estimating the distribution of the assumed population of 87 200 over this assumed residential and manufacturing area, there developed a density ranging from 0.7 of one person per acre to a maximum of 104.6 persons per acre. The average density for the whole area was 10.7 persons per acre. This assumed distribution of population in these 28 districts was used as a basis for estimating the sewage flow in the intercepter so far as the population element entered into such flow.

While the existing sewer system of Fitchburg is on the combined plan, it is the purpose of the present improvement to make some, if not a total, separation of the storm water and sewage. With this end in view the studies relative to the intercepter were based on the assumption that Fitchburg would have a separate system within a few years from the time of the finishing of the intercepter and that surface water would not need to be considered in studying the size or the capacity of the main sewer. This left to be considered the three main factors of domestic sewage, industrial wastes and ground water or other leakage.

The water consumption of Fitchburg varies in accordance with recent measurements from 119 gal. per capita per day to 172 gal. per capita per day. Some of this consumption is probably due to leakage, and that used for manufacturing and steam purposes still further reduces the proportion of this consumption which reaches the sewers. Considering local conditions and also the consumption in other cities, it was decided that the maximum rate of sewage flow from residential districts in Fitchburg would not exceed 150 gal. per capita per day. This would make the maximum of domestic sewage in 1940 about 13 000 000 gal.

The amount of industrial wastes which are likely to find their way into the sewers is very difficult to estimate. Fitchburg is so situated as to make possible the discharge of comparatively clean wastes into the river, and the fact that the paper-making industry constitutes such a large proportion of the manufactories of Fitchburg, the wastes from which the owners would probably not wish to discharge into the sewers, makes it probable that the amount of manufacturing wastes would not be as much as in some other cities. On the other hand, manufacturing sites along the river are now nearly all taken up, and with the opportunity to use electric power from the Connecticut and Deerfield river installations at reasonable cost it seems probable that manufacturing plants will not be located along the river as much in the future growth of the city as they have been in the past. Such manufactories located away from the river would probably contribute more of industrial wastes to the sewerage system than those along the line of the river.

The amount of ground water to be provided for is a factor not easily determined and would probably have a much greater variation depending on weather conditions than either of the other factors. During rains or the melting of snow considerable

quantities of surface water may reach the sewer through perforated manhole covers, and during seasons of heavy rainfall the leakage would be much more than during the drier seasons. Defective joints in pipe sewers will probably be a large element in affecting the quantity of this flow. In this study it was decided to provide for a maximum rate of leakage of 1 960 gal. per acre per day, which in territory completely sewered would be equivalent to about 74 000 gal. per day per mile of sewer.

As a result of the studies described, it appears that the maximum rate of flow for which the intercepting sewer should provide will be about 39 000 000 gal. per day, equivalent to nearly 450 gal. per capita per day, for a population of 87 200 persons, assumed to be a reasonable estimate of the population of Fitchburg in 1940.

The basic data used in the design of the intercepting sewer may be summarized as follows:

Total residential area	6 878.3 acres
Total industrial area	1 256.1 acres
	8 134.4 acres
Population	87 200.0 persons

Average density of population over whole area, 10.7 persons per acre.

Maximum rate of domestic sewage flow, 150 gal. per day per cap.

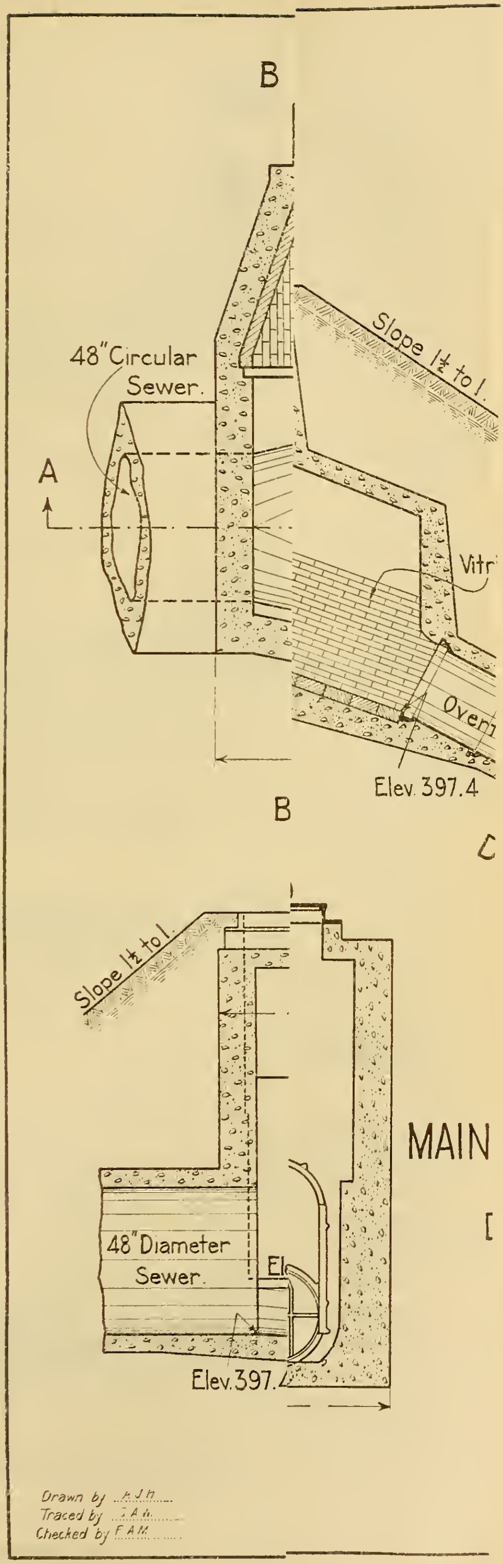
Maximum rate leakage into sewer, 1 960 gal. per day per acre.

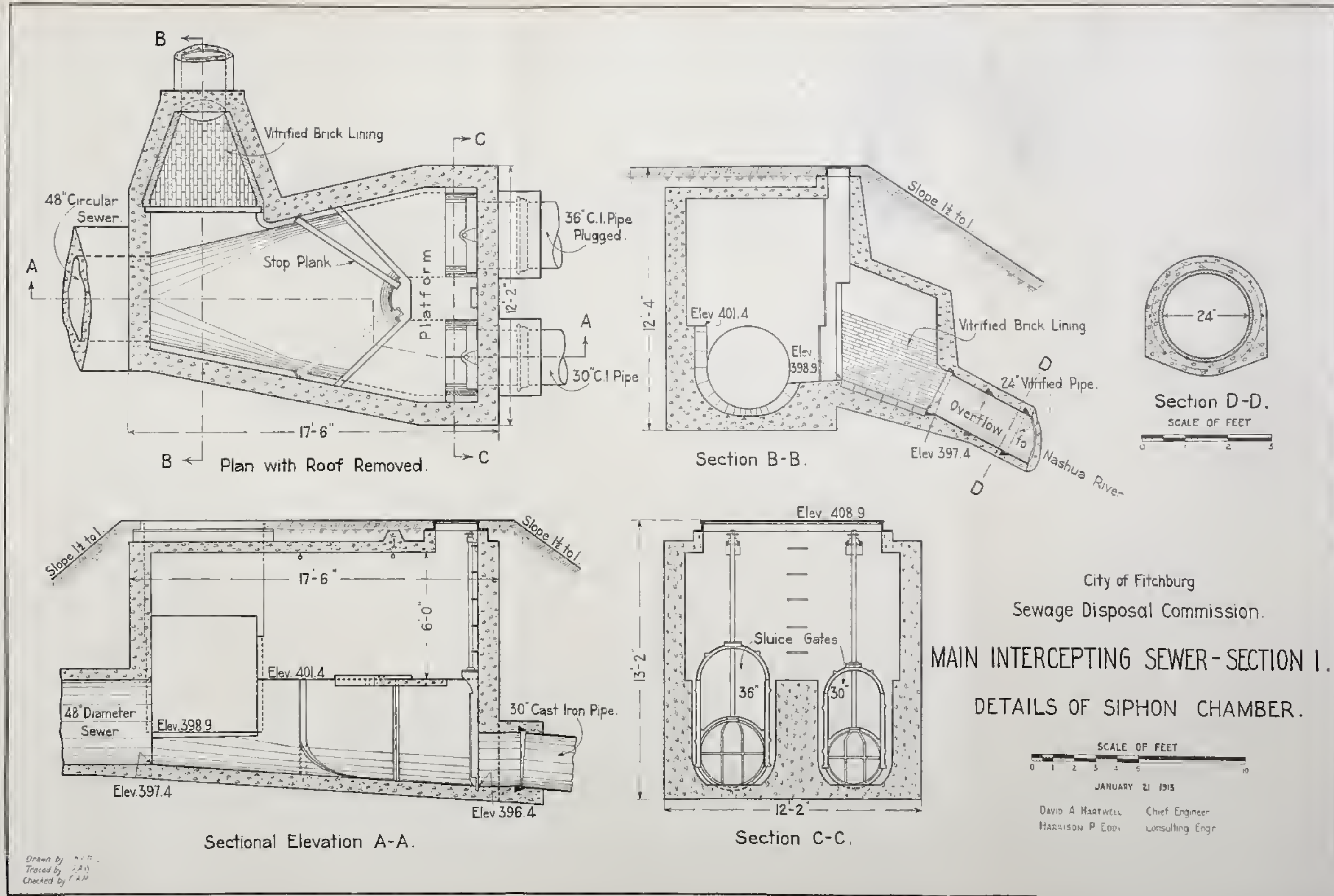
Maximum rate of flow of industrial wastes for industrial area, 8 000 gal. per day per acre.

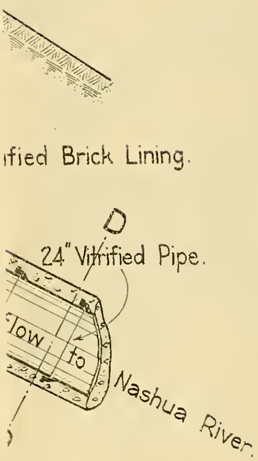
	Gal. per Day.	Per Cent.
Total maximum rate of flow of domestic sewage	13 080 000	33.5
Total maximum rate of flow of leakage	15 943 000	40.8
Total maximum rate of flow of industrial wastes	10 048 800	25.7
Total maximum rate of flow of sewage from all sources	39 071 800	100.0
Total maximum rate of sewage flow per capita	450	

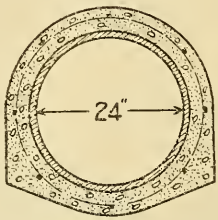
In designing the intercepting sewer, provision has been made for the maximum rate of flow during the day in that season of the year when the quantity of ground water and the leakage into the sewer system is the greatest.

It is probable that this intercepter will be adequate for the flow of sewage tributary to it for a period much longer than that for which it is designed. The design is based on a population for the whole city of 87 200. It is probable when the population of Fitchburg reaches the assumed number that a considerable percentage will be living in the easterly and southerly portions of the city and outside the drainage area tributary to the inter-


B
48" Circular
Sewer.
A
Slope 1½ to 1.
Vitri
Overf
Elev. 397.4
B
Slope 1½ to 1.
48" Diameter
Sewer.
El
Elev. 397.4
MAIN
Drawn by A.J.H.
Traced by J.A.H.
Checked by F.A.M.


B
Vitrified Brick Lining
C
48" Circular Sewer.
36" C.I. Pipe Plugged.
A
Stop Plank
Platform
12'-2"
A
30" C.I. Pipe
17'-6"
B
C
Plan with Roof Removed.
Slope 1½ to 1.
12'-4"
Elev. 401.4
Elev. 398.9
Vitrified Brick Lining
D
24" Vitrified Pipe.
Overflow to Nashua River
Elev. 397.4
D
Section B-B.
24"
Section D-D.
SCALE OF FEET
Slope 1½ to 1.
Slope 1½ to 1.
17'-6"
6'-0"
Elev. 401.4
48" Diameter Sewer
Elev. 398.9
30" Cast Iron Pipe.
Elev. 397.4
Elev. 396.4
Sectional Elevation A-A.
Elev. 408.9
13'-2"
Sluice Gates
36"
30"
12'-2"
Section C-C.
City of Fitchburg
Sewage Disposal Commission.
MAIN INTERCEPTING SEWER - SECTION 1.
DETAILS OF SIPHON CHAMBER.
SCALE OF FEET
JANUARY 21 1913
DAVID A. HARTWELL Chief Engineer
HARRISON P. EDDY Consulting Engr.
Drawn by
Traced by
Checked by





Section D-D.

SCALE OF FEET

0 1 2 3

City of Fitchburg

Sewage Disposal Commission.

INTERCEPTING SEWER - SECTION I.

)ETAILS OF SIPHON CHAMBER.

SCALE OF FEET

0 1 2 3 4 5 10

JANUARY 21, 1913

DAVID A HARTWELL · Chief Engineer
HARRISON P EDDY · Consulting Engr.

cepter. Sewage from such sections, owing to their location, would not be connected with the intercepting sewer. Under such conditions it is probable that the intercepter as designed and partially constructed will be ample in size for the territory for which it is designed, even when the total population of the city is much larger than the assumed population for 1940.

There have been taken for the disposal area about 117 acres of land in Fitchburg and Lunenberg, this area being bounded on one side by the boundary line of the town of Leominster for a distance of over 3 000 ft. About half this area is land very little in elevation above the bed of the river on both sides of which it is located. About 30 acres is of a much higher elevation, and it is this higher land some 40 ft. above the river which will be used for the first installation of the disposal plant. In order to deliver the sewage to the higher elevation by gravity, it is necessary that the portion of the intercepter nearest the disposal plant shall be in the form of an inverted siphon. This siphon has a total length of about one mile. This siphon has been designed with two lines of cast-iron pipe, one 30 in. in diameter and the other 36 in. The 30-in. pipe line has been laid. Although the siphon chamber has been constructed with sluice gates and connections for both the 30-in. and the 36-in. pipe, yet the laying of the 36-in. pipe will not be undertaken until the flow in the intercepter is equal to the capacity of the 30-in pipe, or about 12 000 000 gal. per day. The siphon chamber is constructed with an overflow to the river so that if at times of heavy rain the flow in the main sewer should exceed the capacity of the 30-in. siphon line the excess will be discharged directly into the river. As such discharge will be considerably diluted by rain water, and as at times of such discharge there will probably be a comparatively large flow in the river, such discharge would be sufficiently diluted to prevent any nuisance.

Through the central portion of the city there is no public highway running in the same general direction as the river and near enough to the river to be used to advantage for the location of the intercepter. This necessitated the taking of easements in private land or private passways for about 1½ miles. Studies of the best location for this intercepter through the central part of the city, together with a study of grades, led to the decision to make the minimum grade 1 ft. in 1 000 ft. Constructed on this grade, a 48-in. sewer would give a capacity of 46 cu. ft. per sec. when using a value of $n = 0.013$ and a velocity of 3.72 ft. per sec. This capacity and velocity being sufficient for the requirements,

it was decided to build the lower portion of the intercepter 48 in. in diameter, reducing the size as the different lateral connections would reduce the quantity of the flow to be cared for. Of the total length of the intercepter constructed to date, amounting to 15 033 ft., there is 5 070.7 ft. of 30-in. cast-iron pipe, 3 788.7 ft. of 48-in. concrete sewer, 2 929.6 ft. of 45-in. concrete sewer, and 3 244 ft. of 36-in. concrete sewer. The decision to construct the main sewer with the minimum grade of 1 ft. in 1 000 ft. was made because the velocity, while self-cleansing, would not be sufficient when the sewage was carrying considerable mineral matter to necessitate a brick-lined invert. As the natural slope of the city along the river is about 40 ft. in a mile, and this minimum grade requires only about 5 ft. in a mile, the excess grade was taken care of by steep slopes for distances of about 100 ft. at such locations as seemed best. Some of these grades were as steep as 7 ft. in 100 ft. By this method of concentrating surplus grade, the brick-lined invert has been confined to short distances.

The sewer has been constructed of concrete mixed in proportions of 1 part cement, 2½ parts of sand and 4½ parts of broken stone or screened gravel. Both transverse and longitudinal reinforcement have been used at river crossings, of which there have been four, and about 800 ft. of the 45-in. sewer was constructed in the bed of the river, where the same method of reinforcement was used as at the river crossings. The section of all concrete sewers has been circular, with a thickness of 6 in. of concrete at the invert and crown for 48-in. and 45-in. sewers and 5 in. for 36-in. sewer. Where reinforcement was used, the thickness of concrete was increased about 50 per cent. Blaw steel forms were used on the tunnel lining and on the greater part of the other sections. Wooden forms were used by one contractor and all curved forms were built of wood. As a matter of economy in form expense, all curves in the intercepter were constructed with a radius of 20 ft.

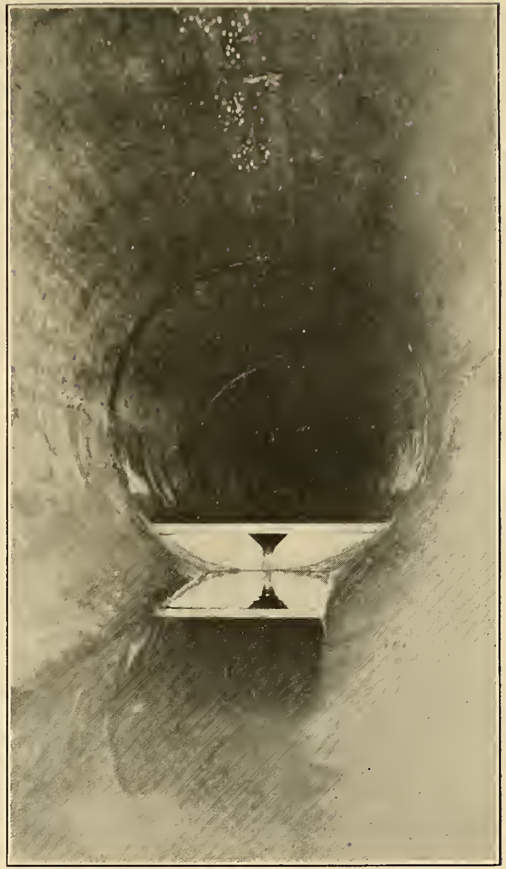
At one location in the central portion of the city, a right of way through manufacturing property was first considered. Such a location for the sewer would have required less expense for construction, but the addition of the cost of the easement would probably have more than equaled the larger cost for construction in the only feasible location in a public way. The location decided upon was some distance removed from the river, and, being at a considerably higher elevation, necessitated either excessive cut or a tunnel, the sewer grade at the maximum point

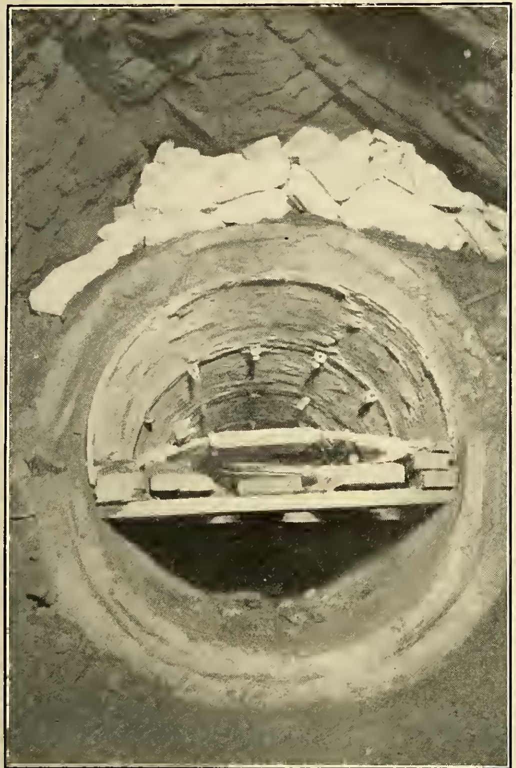
Left.

Flowing Material Encountered in Tunnel Excavation between Fourth and Fifth Streets.

Right.

Weir at Station 93 to Ascertain Ground Water Leakage, 45-inch Sewer.





Left.

Middle Street Tunnel showing Arch Lining and Filling above Arch.

Right.

Grit Chamber looking towards the Outlet End.

being about 45 ft. below the street level. As the geological formation was a stratified rock, and probably self-supporting, it was decided to build this portion of the sewer for a length of about 1 500 ft. in tunnel. The finished sewer at this location is 48 in. in diameter. The tunnel excavation required some timbering at the southerly end for less than 200 ft., but the balance was of very satisfactory formation for tunnel work. At one point the excavation left the rock formation for a few feet, and some difficulty was encountered in attempting to hold the material in place. So far as possible the tunnel excavation was confined to a line 9 in. from the finished barrel of the sewer; the minimum thickness of the concrete lining was 6 in.

As the sewer system of Fitchburg is a combined system, it was considered a necessity to construct a grit chamber somewhere in the line of the intercepter in order to remove as much as possible of the mineral matter in the sewage at times of storm before the sewage entered the siphon. The best location for this chamber was on land owned by the city situated about 1 400 ft. above the siphon chamber. The extreme length of the grit chamber is 53 ft. 9 in., and the maximum inside width is 18 ft. The sump or grit catcher is 31 ft. 6 in. long, 8 ft. wide, and the bottom is 7 ft. below the invert of the sewer. The opening in the sewer invert through which the grit settles into the sump is 6 in. wide and 31 ft. 6 in. long. Iron baffle plates three eighths of an inch thick and located 2 ft. apart are placed across this opening to arrest and divert into the sump such mineral matter as begins to settle by reason of the reduced ve-

Flow and Velocities in Intercepter and Grit Chamber.

Flow.	Gal. per Day.	Cu. Ft. per Sec.	Depth in 4-Ft. Sewer.	Velocity in 4-Ft. Sewer.	Area of Maximum Water Section in Grit Chamber.	Velocity in Grit Chamber.
1910 minimum......	3 000 000	4.65	0.92	2.06	3.99	1.17
1910 average........	4 000 000	6.20	1.08	2.24	6.27	0.99
1910 maximum......	6 000 000	9.30	1.32	2.53	9.97	0.93
1910 storm..........	10 000 000	15.50	1.70	2.91	16.68	0.93
1940 average........	6 875 000	10.65	1.40	2.64	11.32	0.94

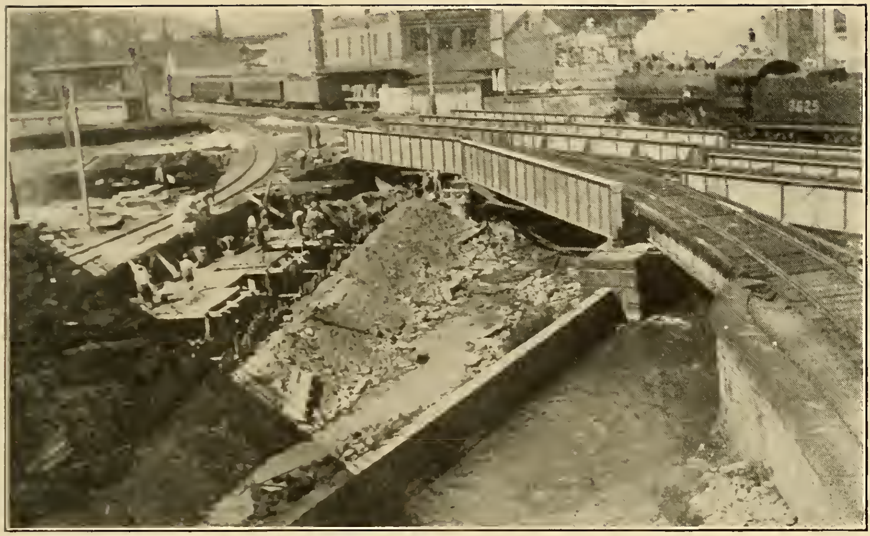
Capacity of 4 ft. sewer with grade of 0.001 = 39.38 cu. ft. per. sec.
Velocity of 4 ft. sewer with grade of 0.001 = 3.13 ft. per sec.
All above computations are with a value of n = 0.015.

locity in the chamber. In designing this chamber it was assumed that a velocity of about 1 ft. per sec. would settle out the mineral matter as desired, but would allow organic matter to be carried along with the sewage.

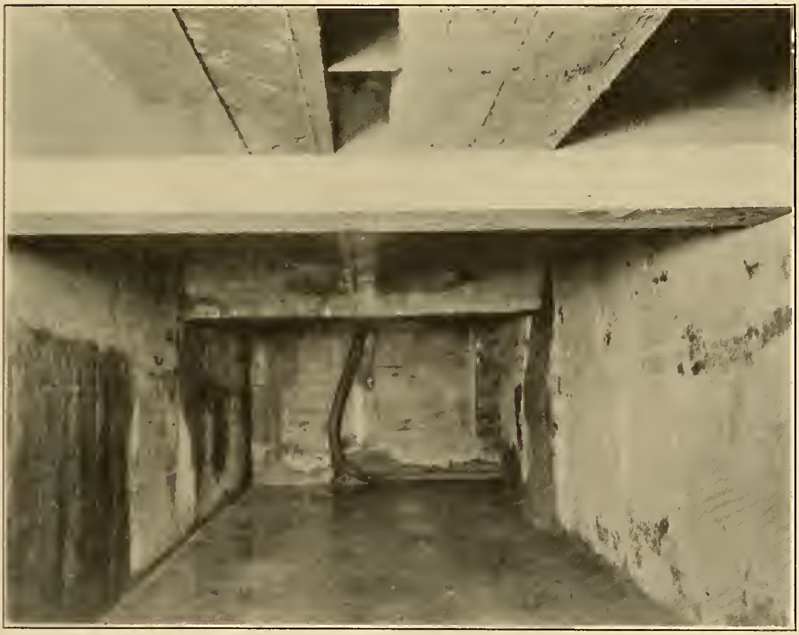
At each end of the grit chamber is a 48-in. sluice gate, and there is a 24-in. bypass of vitrified pipe encased in concrete which allows for diversion of the sewage while the grit is being removed from the sump. A pump well is constructed with the grit chamber in which is placed a 4-in. centrifugal pump with a vertically connected 10-h.p. motor. This pump is installed for the purpose of removing the liquids from the sump before removing the settled material. There are six manholes in the roof and also in the floor of the grit chamber, through which the grit will be removed in buckets. The cost of this grit chamber complete, with all operating appliances, will be approximately $10 000. The grit chamber was built by contract independent of any of the contracts for the main intercepter.

The intercepter thus far completed was built under four contracts. The methods used by the contractors were those usually made use of in open trench work, namely, stiff-leg derricks, cables and trench machines. Outside of the tunnel work, no serious difficulties were encountered in the construction. Owing to the nearness to the river of the location of the sewer, and also to the depth of excavation below the river, there were at times large quantities of water to be cared for by pumping, but at no time was this an occasion of serious difficulty. Pulsometer pumps and centrifugal pumps operated by electric motors were used. Throughout nearly the whole of the concrete section an 8-in. underdrain was laid. The proposals received for constructing the different sections were very satisfactory so far as unit prices were concerned. Rock excavation in trench varied from $3.75 to $6 per cu. yd.; brick masonry in sewer invert varied from $2.50 to $4.34 per sq. yd.; concrete masonry in trench varied from $8 to $11 per cu. yd. and brick masonry in manholes varied from $15 to $18 per cu. yd. Not including engineering or inspection, the cost for 45-in. intercepter was $12.85 per linear ft., or $3.43 per ft. of diameter, and the cost for 36-in. intercepter was $10.42 per linear ft., or $3.47 per ft. of diameter. The cost of the tunnel complete, including shafts, but not including engineering or inspection, was about $23 per linear ft.

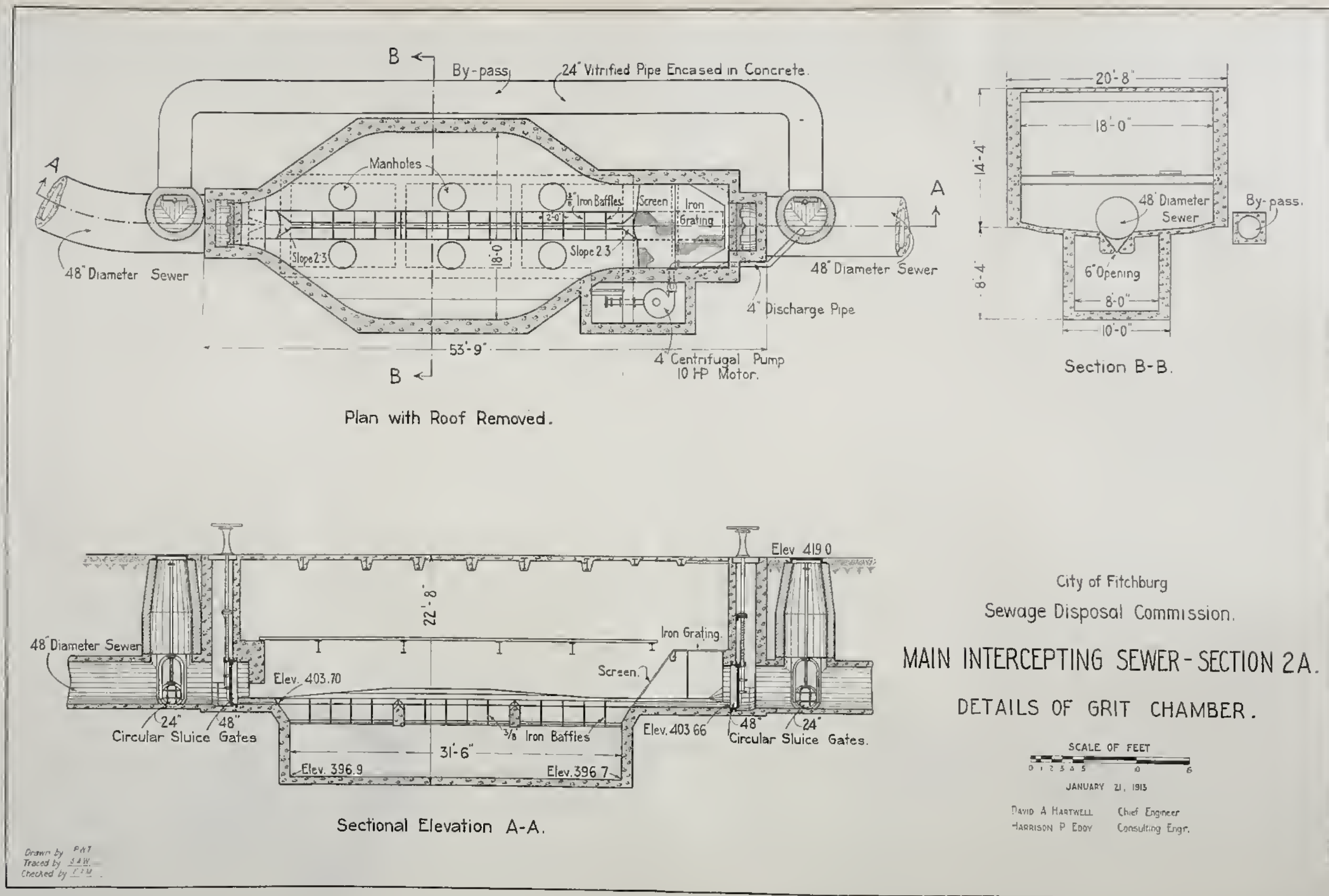
[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 15, 1913, for publication in a subsequent number of the JOURNAL.]



Sewer Trench in River Bed at Boston & Maine Railroad.



Sump or Grit Holder in Grit Chamber.


B
By-pass
24" Vitrified Pipe Encased in Concrete.
20'-8"
18'-0"
14'-4"
A
Manholes
3/8" Iron Baffles
Screen
Iron Grating
2'-0"
A
48" Diameter Sewer
By-pass.
Slope 2:3
18'-0"
Slope 2:3
48" Diameter Sewer
48" Diameter Sewer
8'-4"
6" Opening
8'-0"
4" Discharge Pipe
10'-0"
53'-9"
4" Centrifugal Pump
10 HP Motor.
B
Section B-B.
Plan with Roof Removed.
Elev. 419.0
22'-8"
Iron Grating.
48" Diameter Sewer
Screen.
Elev. 403.70
24"
48"
Circular Sluice Gates
3/8 Iron Baffles
Elev. 403.66
48"
24"
Circular Sluice Gates.
31'-6"
Elev. 396.9
Elev. 396.7
Sectional Elevation A-A.
City of Fitchburg
Sewage Disposal Commission.
MAIN INTERCEPTING SEWER - SECTION 2A.
DETAILS OF GRIT CHAMBER.
SCALE OF FEET
0 1 2 3 4 5 10 15
JANUARY 21, 1913
David A Hartwell Chief Engineer
Harrison P Eddy Consulting Engr.
Drawn by P.H.T.
Traced by S.A.W.
Checked by F.T.M.

MISAPPLICATION OF INTEREST, CONTINGENCIES AND ENGINEERING ITEMS FOR VALUING RAILROADS BY COST OF REPLACEMENT METHOD.

By D. F. Jurgensen, Member of the Civil Engineers' Society of St. Paul.

Since I have been accused of treating somewhat harshly the items, "Interest," "Contingencies" and "Engineering," in my analyses of the same in the article published in the Journal of the Association for December, 1912, Vol. XLIX, page 204, entitled "Railroad Valuation: Reproduction Cost New as a Sole Basis for Rates," I desire to make reply to the criticisms advanced, referring particularly to the discussion printed in the Journal of the Association for February, 1913, Vol. L, page 66.

My paper discussed only the "cost of reproduction new" doctrine as adopted by the Master in Shepard *v.* Northern Pacific Railway Company, which assumes the necessity of presently acquiring and constructing new the identical physical properties of the existing railroad.

Since there is to be no actual reconstruction of existing railroad properties, the assumption is false, but notwithstanding this, the false assumption is by this method treated as an element of value in itself.

It is conceded that the ultimate conclusion sought is the present value of the tangible properties inventoried, which when found is an element in arriving at an amount upon which to compute a return, and I do not understand that my critics claim that "present value" and "cost of reproduction new" are identical.

One critic says, "It is not necessary to conceive any absurdities about railroad construction. The historical records are extant as to how long it took to build each piece of railway." I quite agree that in determining the present value of the tangible properties of railways, the historical records are very useful and valuable, but the cost of reproduction new doctrine, as adopted in Shepard *v.* Northern Pacific Railway Company, as I understand it, prescribes that these historical construction records must not be considered, but carefully ignored.

Interest.

The position I took was that the reconstruction being fictitious, "interest during construction" was equally fictitious or imaginary and depended for its amount upon the caprice of the estimator. To illustrate this, I took for example the three estimates which were made within the space of two years of the cost of reproducing the same system and showed that the item "interest during construction" grew from $23 000 000 in the first to $164 000 000 in the last of these estimates. I understand that my critics do not dispute this statement, but explain the discrepancies by saying that the "basis used for arriving at the amount varied in the different estimates." This statement concedes all that I have claimed. What authority had the appraiser, but his fancies or the exigencies of the case, to vary the base? If the item was an actuality, this could not have been done.

Table "A."

Case.	Date of Valuation.	Total Cost of Reproducing the Northern Pacific Ry. Co.'s System Properties.	Interest during Construction.	
			Total Amount Claimed.	Per Cent. of Total Valuation.
Minnesota........	June 30, 1906	$450 100 288	$39 804 658	8.8+
Spokane.........	March, 1907	460 000 000	23 000 000	5.0
		*446 000 000		5.1
Minnesota.......	April 30, 1908	497 865 035	39 804 658	8.0
Lumber.........	April 12, 1909	622 425 905	164 388 682	26.0+

* Admitted depreciated value.

Calling attention to Table "A," note that the "cost of reproducing new" doctrine, as applied in these cases, valued the Northern Pacific Railway Company system properties at $497 865 035 on April 30, 1908, and that 8 per cent. of this total valuation, amounting to $39 804 658, was interest during construction. On April 12, 1909, not quite a year later, substantially the identical properties were given another application of the same treatment, and the values immediately rose to $622 - 425 905, resulting in an increase in value of $124 560 870 or more than 25 per cent. in less than one year's time. The interest

charge is now more than 26 per cent. of the total valuation and amounts to $164 388 682.

Table "C" shows that the "all track" mileage had increased only 5.11 miles during the latter year. It is difficult indeed to conceive a more ridiculous situation, and this illustration alone should be sufficient to establish beyond question the absolute fallacy of the doctrine.

In these cases, a prosperous and active railroad undertook to make an inventory valuation of its properties to be used as a basis for its charges to the public. The railway was in active operation and not only paying a handsome return to its stockholders but accumulating an immense surplus. Notwithstanding all this, and much more, it was proposed to imagine the road out of existence as a business enterprise for a period of years, during which time it was to be rebuilt by borrowed money and during which time it was to be entirely non-productive; and it was claimed that, in addition to a return upon the physical value of the property actually devoted to the service, the carrier was entitled to rates which would enable it to earn a return upon the amount arbitrarily fixed, as the interest the company would be compelled to pay if each physical condition actually in existence ceased to exist and new conditions not in existence became actualities.

Another criticism was the claim for interest in "Interstate Commerce Commission No. 879, City of Spokane, Wash., et al. *v.* Northern Pacific Railway Company et al.," submitted October 1, 1907; decided February 9, 1909.

In Interstate Commerce Commission reports, Vol. XV, January 1, 1909–April, 1909, page 395, is found:

Cost of Reproduction, Northern Pacific.

"* * * Without attempting to examine these details or to restate the computations, it may be said, speaking always in round numbers, the cost of constructing the roadway of the Northern Pacific Railway Company, as at present existing, was estimated by its engineer at $250 000 000, which included an item of $20 000 000 for contingencies and $23 000 000 for interest. This was stated by the witness to be the cost of reproducing the property at the time he gave his testimony in March, 1907."

The valuation of the Northern Pacific Railway Company in March, 1907, above referred to, may be, for convenience, briefly tabulated as follows:

TABLE "B."

Cost of Reproducing the Property of the Northern Pacific Railway Company, March, 1907.		Deduct for Depreciation.	Present Value, Property of the Northern Pacific Railway Company, March, 1907.
Roadway items........	$207 000 000	$6 000 000	$201 000 000
Contingencies.........	20 000 000		20 000 000
Interest..............	23 000 000		23 000 000
Equipment............	53 000 000	8 000 000	45 000 000
	$303 000 000	$14 000 000	$289 000 000
Right of way and terminal grounds.........	107 000 000		107 000 000
Coal properties........	50 000 000		50 000 000
Grand totals..........	$460 000 000	$14 000 000	$446 000 000

Again quoting from the report of the Interstate Commerce Commission:

"* * * This would give $289 000 000 as a fair value of roadway and equipment, estimated upon the basis of reproducing it in March, 1907; to this cost of construction was added an item of $107 000 000 for right of way and terminal grounds, and still another item, for coal properties, of $50 000 000, making a grand total of $446 000 000 as the fair value of the property of the Northern Pacific Railway Company, upon which it was entitled to earn a suitable return.

"This valuation is by no means a guess. The detailed manner in which it was made has already been given. The prices applied were corroborated by several witnesses of knowledge and standing."

"* * * It seems altogether probable to us that the money value of this property, not including coal properties, based on the cost of reproduction estimated in the manner above stated, would, in the spring of 1907, have equaled at least $325 000 000. The operated mileage of this system as reported in its statistical return to the Commission for the year ending June 30, 1907, was 5 810 miles, and the above valuation would, therefore, mean a total of about $56 000 per mile. * * *"

It must be apparent to any one reading the case in point that the claim for interest amounting to $23 000 000 in the above valuation is for reproducing the Northern Pacific Railway Company's physical properties in March, 1907. It was so understood by the Interstate Commerce Commission after

hearing and considering the evidence presented before it, and how it can at this late day be claimed that said figures, viz., $23 000 000, represent some other item or charge entirely foreign to interest, in the light of the clear language of the intelligent tribunal before which the case was tried, is incomprehensible. If it is meant that in this specific instance interest was figured only on the items entering into roadway, I repeat that the statement establishes the soundness of my position in opposing the item.

It has also been claimed that the estimate prepared for "cost of reproducing the Northern Pacific Railway Company's system property" in the Minnesota case was of the same date as in the Spokane case. This statement is incorrect and not borne out by the records. There were prepared according to the records two estimates for "cost of reproducing the Northern Pacific Railway Company's system property" in the Minnesota case, one dated June 30, 1906, and the other April 30, 1908. The Spokane case estimate was made up as of March, 1907.

TABLE "C."

Case.	Date of Valuation Northern Pacific System.	Operated Mileage.	
		Roadway.	All Tracks.
Minnesota	June 30, 1906	5 429.32	7 694.79
Spokane	March, 1907	*5 810.16	....
Minnesota	April 30, 1908	5 635.19	8 146.45
Lumber	April 12, 1909	5 765.71	8 151.56

* From Statistics of Railways in United States, June 30, 1907.

I stated in substance in connection with my analysis of the item "interest during construction" that "the mileage of the Northern Pacific system at the time these various estimates for this particular item were made was substantially the same as was also the equipment." The records show the mileage of the Northern Pacific system in the Minnesota case as of April 30, 1908, in which the interest claim was $39 804 658, to be 8 146.45 (all track) miles; in the Lumber case, in which the interest claim was $164 388 682, to be 8 151.56 (all track) miles; comparing, we find an actual increase of only 5.11 (all track) miles during the year. Surely no fair-minded person will criticise the treatment accorded this insignificant increase in the *all*

track mileage. See column 4 of Table "C" and columns 4 and 5 of Table "A."

TABLE "D." ENGINEERING.

Case.	Date of Valuation.	Total Cost of Reproducing the Northern Pacific Railway System.	Engineering.	
			Total.	Per Cent. of Total Valuation.
Minnesota..........	June 30, 1906	$450 100 288	$10 539 627	2.3
Minnesota..........	April 30, 1908	497 865 035	11 143 922	2.2
Lumber............	April 12, 1909	622 425 905	10 209 081	1.6

Calling attention to Table "D," note that the "cost of reproducing new" doctrine as applied in these cases valued the Northern Pacific Railway Company's system properties as of April 30, 1908, at $497 865 035, and that $11 143 922 or 2.2 per cent. of this total is engineering on April 12, 1909, when the valuation rose to $622 425 905; i. e., it had *increased* $124 560 870 or 25 per cent. in value during the year, while engineering *decreased* $934 841 or 8 per cent. during the same period. Table "C" shows that the *all track* mileage had increased 5.11 miles during the same period. Could a more glaring illustration of absolute inconsistency be possible than here exhibited?

If the problem was to ascertain the original cost of construction and we had only a statement of the number of yards of material and other items involving construction, together with the prices paid for the work and material, it would be eminently proper to add an estimate for engineering expenses, but no such problem is involved. There is to be no construction. The item as used is, therefore, purely fictitious, and has no place in the inventory.

Complainants' claims in the Northern Pacific case as to original construction cost were given in Complainants' Exhibit, 15 Gray (Vol. 10 N. P. Record No. 599), and show an item of engineering amounting to $3 873 263.16, that amount only having been actually expended on such account for the construction of the entire Northern Pacific system. Note the corresponding figures in Table "D," column 4. Therefore, how can it be claimed that $2 034 636.64 would be a fair amount to assign to Minnesota, which has less than one fifth of the system's mileage?

The item "engineering" is also a purely fictitious one, except when used in connection with and as a part of actual construction cost. So used, the actual amount necessarily expended is an eminently proper item, but as used under the "cost of reproduction" theory is an excellent illustration of the result which must follow, accepting as an actuality an admittedly false assumption. Thus the items upon which this particular item is based can be increased by assuming an increased demand for labor and materials, then the engineering cost is arbitrarily fixed at a percentage of the already improperly increased amounts, and finally, the amount arrived at as reproduction cost is not dependent upon any actual fact or item of property, but upon the whims of the individual making the computation.

Table "E." Contingencies.

Case.	Date of Valuation.	Total Cost of Reproducing the Northern Pacific Railway System.	Contingencies.	
			Total.	Per Cent. of Total Valuation.
Minnesota	June 30, 1906	$450 100 288	$36 186 053	8.0
Spokane	March, 1907	460 000 000	20 000 000	4.3
Minnesota	April 30, 1908	497 865 035	36 186 053	7.3
Lumber	April 12, 1909	622 425 905	41 639 747	6.7

Calling attention to Table "E," note that in the 1906 estimate, contingencies amounted to 8 per cent. of the total valuation, and in the 1909 appraisal, while this particular item was increased $5 453 694 over the 1906 figure, it was reduced to only 6.7 per cent. of the total valuation. The table speaks for itself and no further comment is necessary. As there was to be no actual reconstruction of the property, no contingencies could be encountered.

The profiles and other records of construction indicate where sinkholes and other obstacles were encountered. With this information, the estimator knows the actual quantities and there are no contingencies to provide for except those to be imagined.

Dated at St. Paul, Minn., May 26, 1913.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 15, 1913, for publication in a subsequent number of the Journal.]

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VENTILATION STANDARDS AND VENTILATION METHODS.

BY R. C. CARPENTER.*

[Presented to the Sanitary Section of the Boston Society of Civil Engineers, January 7, 1913.]

THE ventilating engineer has before him the practical solution of the problem of supplying pure air for all purposes wherever it is required. Incidentally he must, in many cases, install means and methods for purifying the air, during which process he must remove smoke, dust, odors, moisture, organic material and other objectionable matter.

Considering the varied industries and the varying character of the demands made, it will at once be perceived that the problems to be solved are complex in their nature and may involve the installation of intricate machinery and the application of complicated chemical processes.

NO DEFINITE STANDARD.

The ventilating engineer in his work has been greatly handicapped in the past by the lack of a definite standard acceptable to all as to what constitutes good ventilation. It is the engineer's business to design machinery and processes for producing definite results rather than to decide just what character the results must have in order to produce satisfaction. In previous years a theoretical standard for good ventilation was assumed, and this standard, without being subject to any physiological investigations, so far as I can learn, has been

* Professor of Experimental Engineering, Cornell University.

almost universally accepted for the last twenty-five years as the criterion of good ventilation.

This standard was based on what was apparently a scientific foundation, although the foundation was merely theoretical. For instance, it has been known for a long time that normal atmospheric air contains about four parts in ten thousand of carbon dioxide. It was known that one of the principal products of respiration was carbon dioxide, or, in other words, that the effect of breathing normal or pure air was to increase the amount of carbon dioxide. An arbitrary limit of carbon dioxide was assumed as the danger point, and a standard of ventilation was based on this constituent. It was assumed, for instance, that ten parts of carbon dioxide in ten thousand of air was the danger limit. On the theory that each person uses one cubic foot of air per minute, which contains normally four parts of carbon dioxide in ten thousand, and that the respired air expelled from the lungs contains four hundred parts in ten thousand of carbon dioxide, a computation would indicate that it would be necessary to supply about 30 cubic feet of air per minute for each person in order to maintain a standard air supply containing ten parts of carbon dioxide in ten thousand. In other words to produce this result the calculations indicate that about thirty cubic feet of air must be supplied for each individual per minute.

This standard of thirty cubic feet per minute has come to be generally accepted throughout the civilized world.

Unfortunately, recent investigations have proved that there is absolutely no scientific basis for the standard which has been so universally adopted and so extensively applied. On the other hand, they indicate that carbon dioxide cannot be taken as the index for proving the unfitness of air for human respiration.

The amount of oxygen in normal air is about 21 per cent. It was generally supposed that the injurious effect of bad air on the human body was largely due to the diminution of oxygen. This constituent was well known to diminish during respiration very nearly as the carbon dioxide increased. Such a deduction is also proved by recent investigation to be erroneous and without any scientific foundation.

A very excellent statement relating to the physiology and processes of respiration is to be found in the twenty-third volume of the eleventh edition of the Encyclopedia Britannica under the heading of "The Respiratory System," and for a full discus-

sion of this subject I would suggest that this article be carefully read.

Sources of Impurities.

The impurities which the air contains are obtained from various sources. Thus, for instance, smoke comes from results of combustion, dust is so universally present that it may almost be considered a constituent of the air. Its sources are, however, exceedingly numerous and may come from manufacturing processes or from winds or various causes. It may be inorganic or mineral in nature, or it may be organic containing bacterial life, depending upon its source. Respiration is a common source of impurities. The air in inhabited rooms is contaminated principally from the products of respiration of the people in the room. The contamination of air by the products of respiration requires the closest investigation on the part of the ventilating engineer.

Respiration Products.

The following table shows the constituents of normal and expired air and is useful in showing the changes brought about in pure air by the process of respiration.

	Normal Air.	Expired Air.
O	20.90	17.3
N	79.04	79.2
Co_2	0.03	3.5

Additional moisture, 6.00 per cent.

This table indicates that by the process of respiration the carbon dioxide is increased by about 3.5 per cent., and the oxygen diminished by 4 per cent. on the basis of dry air. The expired air leaves the body with about 6 per cent. of moisture to be compared usually with about 1 per cent. in the inspired air. It also has temperature approximating that of the human body. The added moisture in higher temperature of expired air makes it decidedly lighter than pure air. The average volume of air inspired per minute by healthy adult men during rest is about seven liters, or $\frac{1}{4}$ cu. ft. During muscular work the volume of air breathed may be six or eight times as much as during rest. The volume of carbon dioxide given off varies from about $\frac{1}{2}$ cu. ft. per hour during complete rest to 5 cu. ft. during severe exertion, and averages about 0.9 cu. ft. per hour. The volume of oxygen consumed is about one seventh greater than that of the carbon dioxide given off.

It was formerly thought that the process of respiration was practically the same as that of combustion and that the greater the supply of oxygen, the greater the formation of carbon dioxide and the greater the supply of useful energy. The physiological investigations referred to show, however, that a very different process takes place, due to the action of the nerves controlling the respiration. These nerves have a source of control in the brain, and operate automatically to maintain a constant percentage of carbon dioxide in the immediate passage leading to the lungs. The effect of this automatic action is to maintain about 5.6 per cent. of carbon dioxide and about 16 per cent. of oxygen in the storage or alveolar space where it is available for use in the lungs. It consequently follows that within such degrees of variation as usually occur in the worst or in the best ventilated room, the amount of oxygen used by the individual does not vary at all. That is, the lungs extract from air which contains only 16 per cent. oxygen just as much oxygen as from normal air, which contains 21 per cent. If, however, the air supplied falls below 15 per cent. in oxygen, then the regulating apparatus cannot overcome the deficiency.

The physiological investigations also indicate that so far as the effect on the human body is concerned, no harm whatever results in supplying air containing thirty to forty times the amount of carbon dioxide which our old theory assumed to be harmful and injurious.

In the ordinary operation of breathing, the percentage of carbon dioxide in the alveolar air is kept remarkably constant. If the air supply is such as not to increase the carbon dioxide in this space, the effect is not noticeable to the patient. The effect of one per cent. of carbon dioxide in the inspired air is negligible. With four or five per cent. of carbon dioxide, however, much panting is produced, for the reason that the percentage of carbon dioxide rises in the chamber preceding the lungs. As a consequence, headache and other symptoms are produced. This is a condition which is practically impossible to realize unless the space were hermetically closed.

Even if oxygen is breathed instead of air, there is no appreciable change in the percentage of carbon dioxide in the alveolar air. Want of oxygen is thus not a factor in the regulation of normal breathing. It is the carbon dioxide stimulus that regulates the breathing, although with excessive muscular work other accessory factors may come in. Thus, for instance, the barometric pressure either higher or lower than normal has a great

effect on the proper regulation of the amount of carbon dioxide and oxygen, but this consideration is not important in connection with ordinary ventilation.

Owing to the unpleasant effects often produced in badly ventilated rooms, it was supposed for a long time that some poisonous, volatile organic matter is also given off in the breath. Careful investigation has not verified this. The unpleasant effects are partly due to heat and moisture and partly to odors which are usually not of a respiratory origin. Carbon dioxide present in the air of even badly ventilated rooms is present in far too small proportions to have any sensible effect. Apparently the unpleasant sensations are principally due to high percentage of moisture and high temperature, the effect of both of which on the action of the heart is injurious.

Various experiments have been made on human subjects enclosed in hermetically sealed boxes provided with windows, which experiments have tended to check or verify the conclusions drawn from the physiological investigations to which I have already referred. Briefly, these experiments have indicated that the human subjects suffered very little or none at all by reduction in the amount of oxygen supplied to from 21 to 16 per cent. and an increase in the carbon dioxide content to nearly 5 per cent., provided the air in the enclosure in which the body is situated is kept in motion, the temperature maintained at less than 74 degrees and the percentage of humidity kept from reaching an excessive amount. If the air is not kept in motion, or if there is excessive moisture or high temperature, suffering is soon evident from the lack of ventilation.

Humidity.

An extremely important property of air is its humidity or moisture content. This is not an impurity, but it needs regulation. Air at a definite temperature has the property of absorbing a certain amount of vapor of water. When the air is so fully charged with this vapor that any increase will be followed by precipitation or rain, it is said to be saturated. Saturated air has the property of coating materials with moisture if the temperature be lowered the very least amount. It would of course for that reason be extremely unpleasant if not unsanitary if introduced into a room for the purpose of ventilation.

The amount of moisture which air will absorb increases very rapidly with an increase of temperature. At very low temperatures the amount is small, say at a temperature of 32

degrees, saturated air contains only 2.35 gr. per cu. ft. At a temperature of 70 degrees, it contains 7.94 gr. per cu. ft.; at a temperature of 100 degrees, it contains 19.12 gr. per cu. ft.

Air in order to be comfortable should contain some moisture. Out-of-doors air is, under usual conditions, from 30 to 70 per cent. saturated and such a degree of saturation is, in accordance with investigations, more sanitary than either extremely dry or extremely damp air. When air is saturated with moisture, water is deposited on all bodies which conduct heat readily and have a lower temperature than the air. On the other hand, if the air is entirely deprived of water vapor, it evaporates moisture from the body, which operation causes an unpleasant sensation. It also takes up a great deal of heat. When the air is saturated, evaporation cannot take place from the body and an unpleasant and depressing effect is produced on the nervous system and the action of the heart. A high temperature in connection with excessive humidity is a frequent source of difficulties with ventilation, and the cause of most complaints as to poor ventilation.

Dust.

A common impurity in the air is dust. This when it exists in large quantities may not be unsanitary but it is certainly a great nuisance, and one of the objects of the ventilating engineer in the purifying of air must be to remove the dust which it contains. The dust may have almost any sort of origin, it may be inorganic or mineral, or on the other hand it may be organic and loaded with injurious bacteria.

Dust has been defined as simply matter in the wrong place, the presence of which had to be tolerated, and it was supposed to serve no useful purpose in nature. Since the year 1880 it has been known to play an important part, and instead of being a nuisance it adds much to the comforts and pleasures of life. Every cloud particle owes its origin to a growth around a nucleus of dust. As a consequence, without particles of dust clouds would be impossible. The presence of dust in the atmosphere allows the condensation of the vapor to take place whenever the air is cooled to the saturation point. If there were no dust present, condensation would not take place until the air was cooled far below that point. Under such conditions, when it did take place it would result in heavy rain drops without the formation of what we know as clouds. This would result in many disadvantages. The super-saturated air having no dust

to condense on would condense on our clothes, the inside and outside walls of our dwellings and on every solid and liquid surface with which it came in contact.

Without atmospheric dust, we should not have the glorious cloud scenery which we at present enjoy. We should have no haze in the atmosphere, we should have no twilight. Darkness would come as soon as the sun passed below the horizon.

The relative humidity of the air has a great effect on the dust by increasing the size of the particles of water vapor and so increasing the haze. The number of dust particles rapidly decreases with the amount of moisture present.

Thousands of tests have been made of the distribution of dust over the world, and these tests indicate that in the air over cities like London and Paris the number of dust particles may rise to an amount as great as 100 000 to 150 000 per cu. cm.

Even the purest air contains a considerable number of dust particles. The mean of a number of observations of air over the Atlantic showed 338 dust particles per cu. cm. In the purest country air the number is rarely below 10 000 per cu. cm. (1 cu. cm. =about 1-16 of a cubic inch.)

Smoke.

The air is frequently charged with smoke particles. In a general way, smoke particles are to be considered as a peculiar character of dust. They are peculiarly disagreeable because the particles are generally black in coloı and consequently render everything on which they settle of a disagreeable black and sooty color. The disagreeable part of smoke from the ventilation standpoint consists of the small particles of carbon which float in the air. Whether or not these particles are unsanitary directly is a proposition regarding which there is difference of opinion. It is, however, certain that they cause an immense economic loss by discoloring buildings and by soiling clothing, house furnishings and everything that pertains to life. Smoke particles are frequently of considerable size and are retained in the nostrils to a considerable extent during the processes of respiration. In that way they may have a deleterious effect on health.

As is well known, smoke is a product of combustion which would not occur, at least to any sensible amount, if the combustion were perfect. It is, therefore, of itself an evidence of economic waste. While I shall not have time to make any discussion whatever of the smoke problem, I would state that

it is very largely preventable by the installation of proper appliances and proper methods of operation of plants which produce it.

The remedy for smoke is its "prevention" rather than its removal, and smoke prevention is possible with good devices and good operation. Time will not permit a further discussion in this talk.

Odors.

The air is frequently not only loaded with dust which it may be necessary to remove in order to bring it to a proper sanitary condition, but it may also be odorous or smelly. It a way, odors might be treated as pertaining to the same class of deleterious substances as dust, but they have a property not possessed by ordinary dust of affecting the organs of smell.

Odors vary greatly in character and have great effect upon the nervous organism of the human body. Many odors are extremely pleasant, and some have an exhilarating effect, while other odors are extremely unpleasant and have exactly the reverse effect. Unfortunately, all people are not agreed as to the character of odors. Gases that smell pleasant to some people are extremely unpleasant to others. As an illustration, the odor of cooking may be pleasant to some, whereas to others it may be extremely unpleasant. Odors are not necessarily harmful, and generally speaking they do good rather than harm. Odors are produced by a great variety of substances, and, as stated above, vary in quality from the most disagreeable nature, which is almost sufficient to cause sickness, to the most pleasant and delightful nature such as characterize our most expensive perfumes. A great majority of the disagreeable odors in chemical composition are complicated compounds of carbon and hydrogen. They may differ from each other by small variations in composition less in amount than the character of the odors would indicate. It is well known that many of the desirable perfumes, such as the odor of wintergreen, of orange blossoms, of violets, are produced artificially by the combination of the required chemical compounds.

In all cases the natural scents are complex mixtures of many ingredients, and a variation in the amount of any one may completely alter the scent. Such mixtures would be difficult to reproduce economically. The perfumer is content with a product having practically an identical odor which may be formed artificially.

The ammonia compounds consisting of nitrogen and hydrogen are extremely odorous and are very penetrating and unpleasant.

The odorous gases, with scarce an exception, are combustible and are converted by the process of combustion into carbon dioxide, water and other non-odorous materials. Certain odorous gases like ammonia are absorbed in large quantities by water, and although by that process the odor is not removed, the air is however very greatly purified.

As with respect to smoke in many cases it may be easier to prevent odors than to remove them.

Air Purification or Conditioning.

Air purification as practiced at the present time removes from the air dust and smoke particles and regulates the proper degree of humidity and temperature. This process is usually called at the present time " air conditioning."

Apparatus for conditioning air as defined above is now installed in many important structures, and the future demand for sanitary results is likely to lead to its almost universal use. It is also successfully installed in special industries which are of such a character as to require definite temperatures and definite degrees of humidity.

I will describe briefly only a few of the features of the air conditioning process as now successfully applied.

Dust particles are to a great extent precipitated by moisture, as may have been noted from the statements which I have already made. Consequently the process ordinarily employed for the removal of dust is a system of washing which consists in the use of a great many extremely fine sprays. The mist produced by the sprays has the property of surrounding every dust particle with sufficient moisture to cause the dust particle to be precipitated and put in a position where it may be removed with the removal of the water. Formerly it was customary to remove dust particles by passing air through cloth filters which were kept continually wet, and such filtering processes may still be found in operation. But I believe that new filtering plants are at the present time not being installed to any great extent, while the spray washing systems are being installed to a great extent.

Air always contains water vapor. The maximum weight of water vapor which can be absorbed by the air is a function of

the temperature. The relation between the maximum weight of water vapor and the temperature has been quite recently very carefully investigated by Mr. W. H. Carrier, of Buffalo, N. Y., and has been made the subject of a paper before the American Society of Mechanical Engineers (December, 1911). When the air is loaded with a maximum amount of water vapor, the least fall of temperature will cause precipitation. The amount of water vapor carried by the air in percentage of the total amount is its percentage of humidity. For the reasons stated above, if the temperature of the air be changed without increasing the moisture content, the percentage of humidity will also be changed, but in a reverse direction. External air is found with a variable percentage of humidity, but it is considered in the most desirable condition when it contains from 30 to 60 per cent. of humidity, as explained above, understanding that 100 per cent. humidity indicates saturated air.

Automatic devices have recently been perfected for varying the moisture content of the air automatically so as to maintain it at any desired percentage of humidity. This apparatus works on the principle of a double, differential thermostat, one part of which is moved by the temperature of the wet bulb thermometer and the other by the temperature of the dry bulb thermometer in such a way as to give a differential action arranged to supply or cut off the supply of moisture as desired to maintain a constant percentage of humidity corresponding to a constant temperature difference between a dry and wet bulb thermometer for a given temperature.

The washing of the dust particles from the air frequently charges the air with an excess of moisture so that the apparatus for air conditioning must be provided with means for separating or taking out excessive water if necessary.

Air conditioning usually requires the control of the temperature of the air, and this in turn requires heating coils which are under thermostatic control so as to bring the air passing through to the desired temperature.

Time will not permit any further discussion of air conditioning processes, but enough has been said to indicate that the subject is of itself an extensive one and could profitably be made the entire subject of an evening's meeting.

General Practical Remarks.

The ventilating engineer is under the serious handicap of not having a definite standard to work by which would enable

one to judge of the perfection of his work. His work is naturally of a varied character. First, he must introduce the proper quantity of air to supply the necessary amount required for the best sanitary conditions; second, he must purify that air so as to remove from it objectionable dust, smoke or odors and regulate its humidity; third, he must introduce this air at the desired temperature; and fourth, distribute it uniformly in the rooms which are to be ventilated.

I shall not discuss further the standard requirements as to the amount of air necessary for sanitary purposes. I have pointed out to you that the scientific reasons underlying the present standard requirement were unsound. I have not said, however, that any other standard for quantity would have been better nor that it is desirable in the future to change the requirement as to the amount of air to be supplied. Without doubt, it is true that so far as quality is concerned our best standard is the external air surrounding the building to be ventilated. Investigation also indicates that the utilization of the external air for natural ventilation by raising the windows and regularly admitting the air to the apartment to be ventilated is desirable when the conditions are favorable. Generally speaking, it is not desirable to have a system of ventilation which will not permit the direct communication with the outside air by the opening of windows. It however must be recognized that no supply of a definite amount can be obtained by merely connecting a room with the outside air by opening a window, and that as a consequence a system of ventilation which depends alone on the opening of windows will be certain to fail and will be certain to give air which will differ largely from the external air surrounding the building.

In order to meet the requirements which I have stated above are necessary for good ventilation, in my opinion, the engineer must introduce into the room where ventilation is required the desired amount of air, which air has been purified and put in the most desirable humidity condition for respiration. This air should be introduced at a moderate temperature and at a temperature sufficiently low never to make the occupant uncomfortable and should be uniformly distributed throughout the room.

[NOTE.—Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 15, 1913, for publication in a subsequent number of the JOURNAL.]

SPACE OCCUPIED BY WATER TUBE BOILERS.

By C. R. D. Meier.

[Read before the Engineers' Club of St. Louis, April 30, 1913.]

The practice of driving boilers at loads considerably higher than the older rating of 10 sq. ft. per boiler horse-power results in a saving not only in the first cost of boilers and boiler accessories, but also in the cost of real estate, foundations and the power-plant building. The latter savings are often greater than that of the cost of the boilers proper, especially where real estate is expensive.

The space occupied by the boilers per rated horse-power, that is, irrespective of the rate of driving, also influences the first costs. As will be shown in the following pages, the additional space occupied by some types of boilers as compared to others will amount to $1 to $10 per h. p. added first costs.

The Influence of Tube Size and Arrangement.

The space occupied by a given area of tube surface will be determined by the size of the tubes, the spacing and arrangement of the tubes and the design of the boiler.

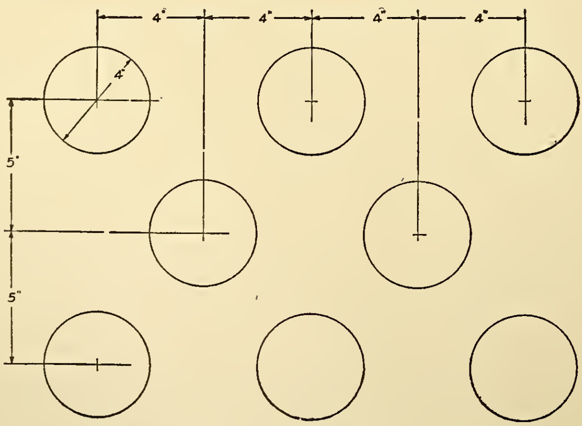


Fig. 1. Tube Spacing in Types B and D Boilers.

With vertical baffle, three and four pass boilers (Types B and D), the tubes are usually 4 in. in diameter, spaced according to the sketch of Fig. 1. The tubes are staggered with centers 8 in. apart on the horizontal rows and 10 in. on the vertical rows, and with an additional row of tubes staggered in between.

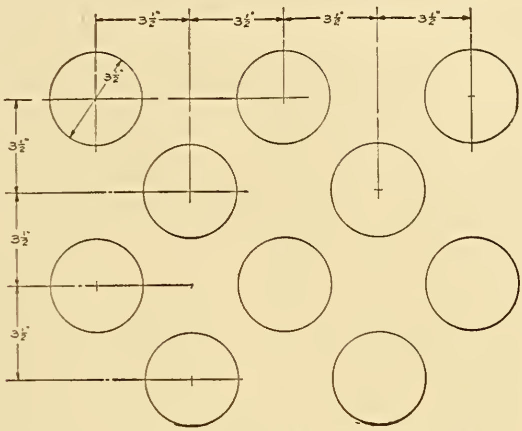


FIG. 2. TUBE SPACING IN TYPE A BOILER.

With the horizontal baffle boilers (Type A), the tubes are $3\frac{1}{2}$ in. in diameter, arranged on equal centers in every direction, as shown in the sketch of Fig. 2. The top of each row of tubes is on line with the bottom of the row immediately above it. With this spacing and $3\frac{1}{2}$ in. tubes, the total height of four rows of tubes is 14 in., which is exactly the height required for three rows in Fig. 1. The tubes in this type being $3\frac{1}{2}$ in. in diameter, as against 4 in. in types of boilers illustrated by Fig. 1, there would be a considerable saving in space occupied even if the distance vertically between tubes were $8\frac{3}{4}$ in., which could correspond to 10 in. in Fig. 1. Actually, the tubes are spaced vertically on 7-in. instead of $8\frac{3}{4}$-in. centers and therefore there is an additional decrease in space occupied.

In the Type C boiler with inclined vertical tubes, the tube diameters are $3\frac{1}{4}$ in., but, in order to permit of removal of tubes, they cannot be spaced closely nor can they be staggered. For this reason the saving in space, due to the use of smaller tubes, is offset by the wide spacing. The inclined vertical arrangement tends to reduce floor space but requires greater head room, as will be shown.

Another point to be noted about this type of boiler is that it imposes limits on the space available for grates or stokers.

The lower water drum or drums cannot be exposed to the direct heat of the fire.

DIMENSIONS OF SEVEN WATER TUBE BOILERS OF THE SAME RATED CAPACITY.

The figures in the following analysis are based on blue prints submitted by a number of boiler manufacturers on a recent municipal job. The boilers were of large size for heavy overload capacity and high pressure. The designs offered therefore are typical of the most modern boiler plant requirements.

The drawings of Fig. 3 to 9 have been prepared on the basis of these blue prints (Fig. 5 is based on Fig. 4). The boilers are all of 9 000 sq. ft. boiler surface, and all dimensions are based on an 8 ft. setting.

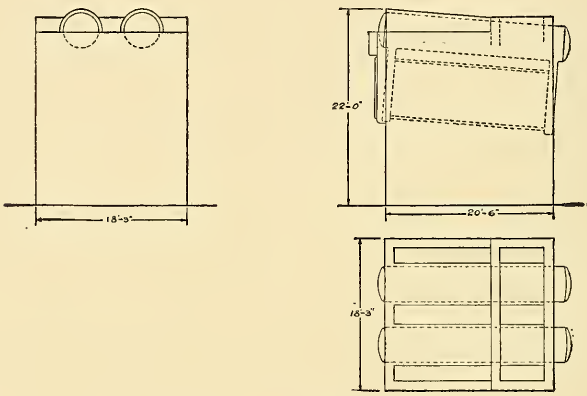


FIG. 3. TYPE A BOILER.

Fig. 3 shows Type A, the horizontal pass type boiler, with which the floor space is 20 ft. 2 in. by 17 ft. $7\frac{1}{2}$ in., while the height of the boiler is 22 ft.

Fig. 4, 5 and 6 (Type B) show three types of vertical baffle, horizontal water tube boilers, Fig. 4 with inclined headers, Fig. 5 with vertical headers, reducing the floor space somewhat, and Fig. 6 with the cross drum and vertical headers, reducing the head room.

Fig. 7 and 8 (Type C) are inclined vertical tube boilers. Fig. 8 is a modification of the Fig. 7 design, and while this arrangement reduces the width of the boiler, it increases the depth, which is over 27 ft., and at the same time this type of boiler has the largest vertical dimension.

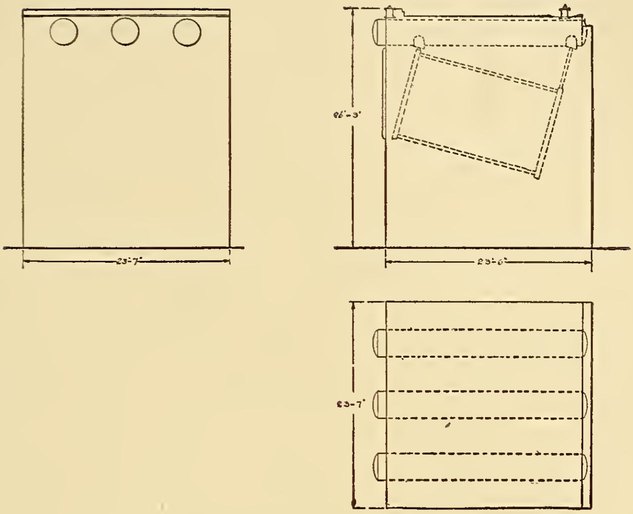


FIG. 4. TYPE B BOILER, WITH INCLINED HEADERS.

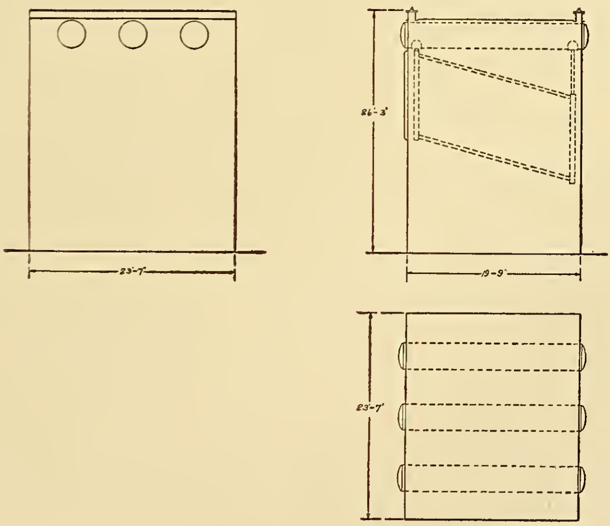


FIG. 5. TYPE B2 BOILER, WITH VERTICAL HEADERS DECREASING FLOOR SPACE SOMEWHAT.

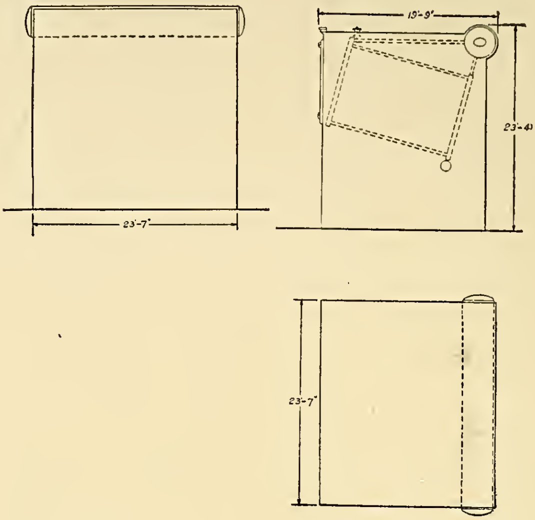


Fig. 6. Type B3 Boiler with cross steam and water drum, decreasing head room somewhat.

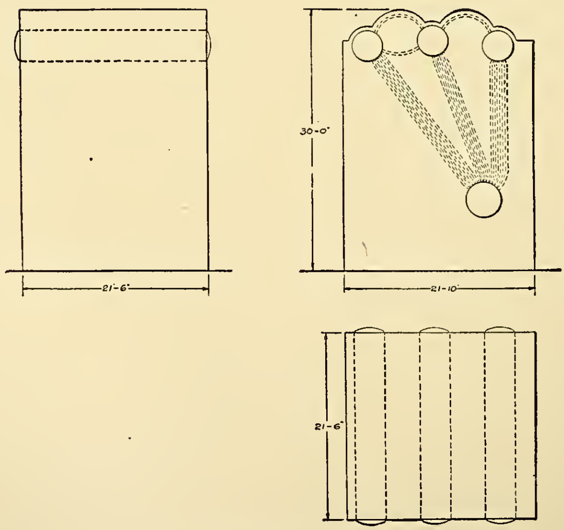


Fig. 7. Type C1 Boiler of standard setting.

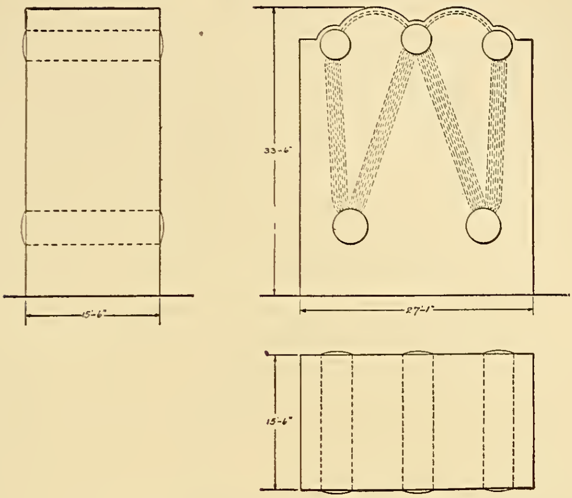


FIG. 8. TYPE C2 BOILER ARRANGED WITH A-SHAPED FURNACE.

Fig. 9 is another style horizontal boiler (Type D), having steel waterlegs instead of the sectional headers of the types in Fig. 4, 5 and 6, but with 4-in. tubes, vertical baffles and tube spacing similar to Fig. 1, so that the space occupied is approximately the same as that of Type B.

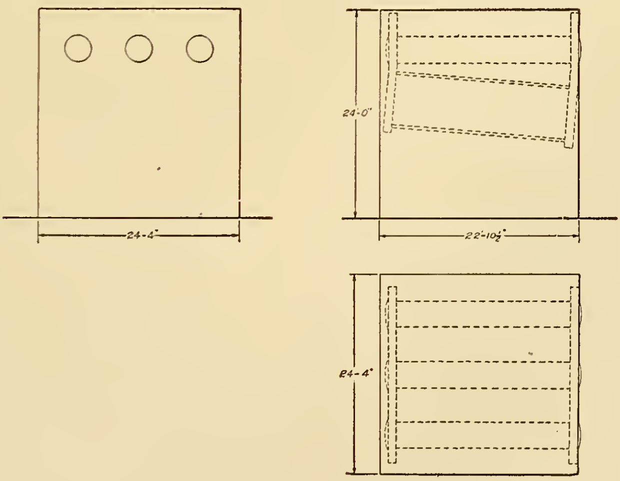


FIG. 9. TYPE D BOILER.

Comparative Floor Space required for a Typical Installation of Eight Boilers of the Various Types.

To compare the space occupied per rated horse-power by the various types of boilers we will consider a typical installation of eight boilers as shown in Fig. 10. With the Type A boiler, alleys will be required between each battery of two for most stoker installations, but it is to be emphasized that for hand-firing and some stokers the entire eight boilers may be set solid, thus further decreasing the size of the boiler room.

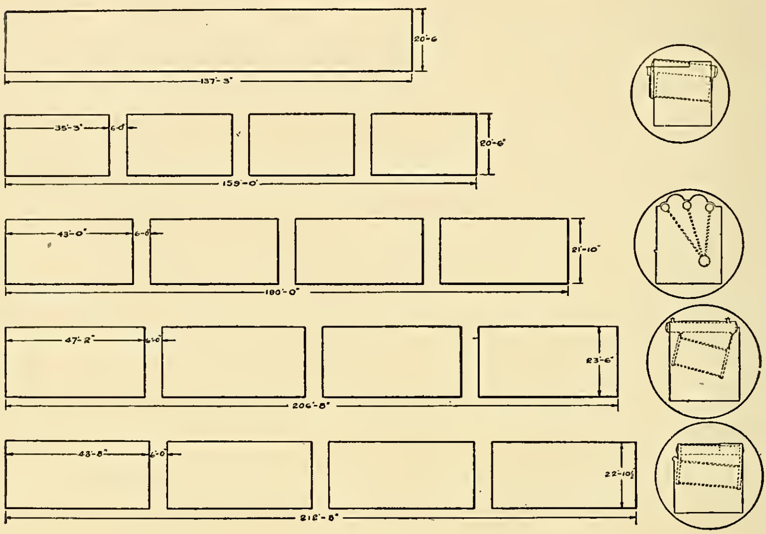


Fig. 10.

Floor Space for eight boilers of 9 000 sq. ft. heating surface each; Type A without alleys and with 6 ft. alleys in batteries of two. Also Types C, B and D, arranged with 6 ft. alleys and in batteries of two boilers.

Boilers of this type may be set solid because there are no side cleaning doors, the soot being blown by a system of steam nozzles inserted through the hollow staybolts in the front and rear headers.

With this exception all of the various types of boilers as shown in Fig. 10 are set with 6-ft. alleys between each battery of two boilers, and the comparative space required may be readily gaged from this illustration.

Table 1 gives the total floor space occupied by eight boilers of the different types, also the floor space per rated horse-power for boilers only, and the square feet of boiler room floor space

TABLE 1.

Type of Boiler.	Sq. Feet for Boilers Only.	Sq. Ft. per Rated H.P. for Boilers Only.	Sq. Ft. of Boiler Room (Total) per Rated H.P.	Add'l Space compared to Type A without Alleys.		Add'l Space compared to Type A with Alleys.	
				Sq. Ft. H.P.	Per Cent.	Sq. Ft. H.P.	Per Cent.
Type A without alleys between batteries	2 813.6	0.392	0.784	00	00	....	...
Type A with 3 alleys	3 233.9	0.448	0.896	0.112	14.6	00	00
Type B_1	4 856.8	0.675	1.350	0.566	72.2	0.454	50.6
Type B_2	4 081.7	0.567	1.134	0.350	44.6	0.238	26.5
Type B_3	4 081.7	0.567	1.134	0.350	44.6	0.238	26.5
Type C_1	4 147.7	0.575	1.150	0.366	46.7	0.254	28.3
Type C_2	3 845.4	0.534	1.068	0.284	36.2	0.172	19.2
Type D	4 799.9	0.666	1.332	0.548	70.0	0.436	48.5

per horse-power, allowing 100 per cent. additional space for firing aisle, etc. From this is obtained the additional square feet of surface per horse-power as compared to Type A without alleys between the boilers, and also the additional floor space per horse-power as compared to Type A with the alleys. In both cases the additional floor space is also expressed in percentages. For example, it will be noted that the Type B boiler requires 72.2 per cent. more floor space than the Type A without alleys, and 50.6 per cent. more floor space than the Type A with alleys. This type of boiler requires the greatest additional floor space, while the Type C_2, the least additional floor space, i. e., 36.2 per cent. and 19.2 per cent. as compared to the Type A without and with the aisles respectively. However, this type of boiler, while requiring less additional floor space, requires the greatest additional head room.

Table 2 gives the height of the various types of boilers, the additional height in feet compared to Type A, and the additional height in per cent. compared to Type A. The Type C_2 is 52.3 per cent. higher than the Type A. The figures for height of boilers are based on measurement from the floor to the top of the highest part of the boiler drums. All the boilers have the same setting, i. e., 8 ft. The vertical dimension remains the same, whether a superheater is used or not. With the Type A it will be noted that the superheater occupies space which would be available in any case because of the room required for the steam piping and the smoke breeching.

TABLE 2.

Type of Boiler.	Height in Feet.	Add'l Height compared to Type A.	Per Cent. Add'l Height compared to Type A.	Additional Cost of Boiler Plant Building on account of Greater Height in Dollars per H.P.
			Per Cent.	
Type A	22.00	0	0	$0.00
Type B_1	26.25	4.25	19.3	0.24
Type B_2	26.25	4.25	19.3	0.24
Type B_3	23.6	1.60	6.8	0.09
Type C_1	30.0	8.00	36.4	0.46
Type C_2	33.5	11.50	52.3	0.65
Type D	24.0	2.0	8.7	0.11

The Money Value of Floor Space.

The money value of space saved will depend on —

(1) The cost of real estate.

(2) The cost of foundations.

(3) The cost of the power plant building.

Power plants, factories and industrial plants are generally located where real estate is cheap, but nevertheless in many cases the cost of the site will be 50 to 100 per cent. of the cost of the building itself. (See *Power*, January 26, 1909, page 219.)

The cost of the generator station building, and the land occupied, of the Edison Electric Illuminating Company of Brooklyn, is $29 per kw. (see *Engineering and Contracting*, April 6, 1910), and as the cost of the building probably lies between $10 and $20, the land and the building are about equally expensive.

As against this upper extreme, we have such plants as factories in outlying districts of small towns where the cost of real estate might be as low as 25 cents per sq. ft. In between lie the factories, breweries, mills and similar plants, in medium-sized cities. We must also consider isolated plants in cities and will assume the following limits for the value of real estate:

Real Estate, 25 cents to $10 per sq. ft. . . . . (1)

In a paper on "Steam Power Plants," by O. S. Lyford and R. W. Stovel, in the January, 1911, Proceedings of the Engineers' Society of Western Pennsylvania, it is pointed out that foundation costs range from $1.25 to $4.00 per sq. ft. of building plan area, depending upon the character of the soil. The lower figure covers simple concrete footings for good bearing soil,

while the higher figure covers locations where piling or rock excavation is required. We will assume the same figures, viz.:

Foundations, \$1.25 to \$4.00 .... (2)

The same paper states that power-plant buildings cost \$4 to \$12 per kw., and that the plan area will average from 0.8 to 1.5 sq. ft. per kw., giving a cost per square foot of from \$2.70 to \$15.00.

Power, of August 22, 1911, page 274 (Mr. A. E. Dixon), cites a case of a power-plant building in the Middle West of 1 600 kw. where the building cost was \$2.35 per square foot. The author also states, "In many of the larger steam plants the cost of the building per square foot is much higher than the figure for this plant, ranging from \$5 to \$10 without foundations."

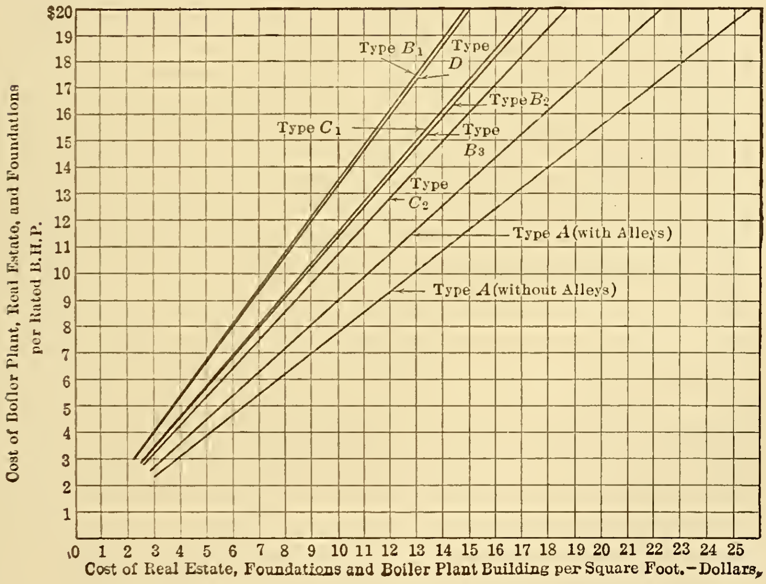


FIG. 11. SHOWING RELATION OF COST PER SQUARE FOOT OF FLOOR SPACE AND COST PER B.H.P. WITH VARIOUS TYPES OF BOILERS.

Data, Chicago, for September, 1910, gives a chart with six cases of power-plant buildings varying in plan area from about 3 000 to 30 000 sq. ft., varying from \$2 to \$4 per sq. ft.

On the basis of the foregoing, we will assume:

Cost of Buildings, \$2 to \$8 per square foot of plan area ... (3)

Grouping the three items of real estate, foundation and power-plant building, we have the following:

Real Estate, cost per sq. ft..........	$0.25 to	$10.00
Foundations, cost per sq. ft.........	1.25 to	4.00
Power Plant Buildings, cost per sq. ft.,	2.00 to	8.00
	$3.50	$22.00

The chart of Fig. 11 is drawn with the above limits of cost per square foot of space and shows the cost of floor space per b.h.p. Taking the cost per square foot as $10, for instance, we note that the cost per boiler horse-power with Type A is $7.84; with Type A with alleys, $8.96; with Type C, $11.50; Type B, $13.50, and Type D, $13.32.

Money Value of Head Room.

The different head room requirements with the boilers under consideration have already been given in Table 2. It now remains to determine the money value of head room so that these costs may be properly combined with the floor space figures.

We can assume $5 per boiler horse-power as an average cost of a boiler plant building alone, as corresponding to the average value of $10 per sq. ft. for the cost of building foundations and real estate, taken above. It is unnecessary to analyze the money value of head room for a range of values of boiler plants from minimum to maximum because this item is less important than floor space.

Obviously, the height of the boiler-plant building will not affect the cost of real estate and for all practical purposes the cost of foundations. Furthermore, increasing the height of the boiler room does not increase its cost so much in proportion as does an increase in the plan area of the building. The reason for this is that the side walls and columns may be increased in height at a less cost than the roof construction.

We will therefore assume that doubling the height of the building increases its cost only 50 per cent., whereas if the cubical contents were increased the same amount by making the floor plan area double, the cost would be increased 100 per cent.

In the second place, increase of a certain percentage in the height of a boiler does not increase the height of the boiler room by the same amount; the clearance above the boilers remains practically the same in any case. We will therefore make the

further assumption that an increase in the height of a boiler of 100 per cent., instead of increasing the height of the boiler room by 100 per cent. increases that dimension only 50 per cent.

Now, referring to Table 2, it will be noted that a last column has been added, giving the additional first cost due to increased height of each boiler as compared with the Type A. Take, for instance, the Type C_2 which is 52.3 per cent. higher than the Type A. On the basis of the foregoing assumptions, the boiler room would have to be only one half of 52.3 per cent., equal to 26.2 per cent., higher, and this will increase the cost of a boiler room only one half of 26.2 per cent., equal to 13.1 per cent. The boiler room costs $5 per boiler horse-power, which, multiplied by 13.1, equals $0.65, as given in the last column, as the added cost for the Type C_2 as compared with the Type A, on the score of head room.

Total Saving per B.H.P.

Sum of Floor and Head Room Savings.

Table 3 summarizes the savings due to decreased floor space and head room of the Type A boiler, as compared with others, based on the Type A with and without six-foot alleys between batteries. The saving in floor space is evaluated on a basis of $10 per sq. ft., which is a fair average. The costs due

TABLE 3.

Type of Boiler.	Add'l Cost per Boiler H.P. on basis of $10 per Sq. Ft. of Plan Area.		Add'l Cost per H.P. due to greater head room from Table 2 compared to A.	Total Add'l Cost per Boiler H.P. for average conditions of cost of real estate, foundations and building of $10 per sq. ft., and add'l height (as per Table 2).	
	Compared to Type A without Alleys.	Compared to Type A with Alleys.		Compared to Type A without Alleys.	Compared to Type A with Alleys.
Type A without alleys..........	$0	...	...	$0	...
Type A with alleys..........	1.12	$0	$0	1.12	$0
Type B_1........	5.66	4.54	0.24	5.90	4.78
Type B_2........	3.50	2.38	0.24	3.74	2.62
Type B_3........	3.50	2.38	0.09	3.59	2.47
Type C_1........	3.66	2.54	0.46	4.12	3.00
Type C_2........	2.84	1.72	0.65	3.49	2.37
Type D.........	5.48	4.36	0.11	5.59	4.47

to greater height are taken from Table 2, in which the calculation was made on a basis of cost of a boiler-plant building of $5 per h.p., which would correspond to the figure of $10 per sq. ft. for buildings, real estate and foundations.

It is seen that compared with the Type A without alleys (for hand firing and a few types of stokers), the additional cost with the various other types of boilers ranges from $3.49 to $5.90 per h.p. And compared to the Type A with alleys (the general conditions for stokers), the additional cost ranges from $2.37 to $4.78 per b.h.p. If instead of considering the one basis of $10 per sq. ft. we consider the upper and lower limits of $22 and $3.50, it is evident that the saving in space occupied with the Type A boiler, as compared with the various other types, is worth from $1 to $10 per b.h.p.

Appendix.

Fig. 12 is reproduced from a set of curves in an article entitled "*Neue Bestrebungen im Dampfkesselbau*," by F. Mün-

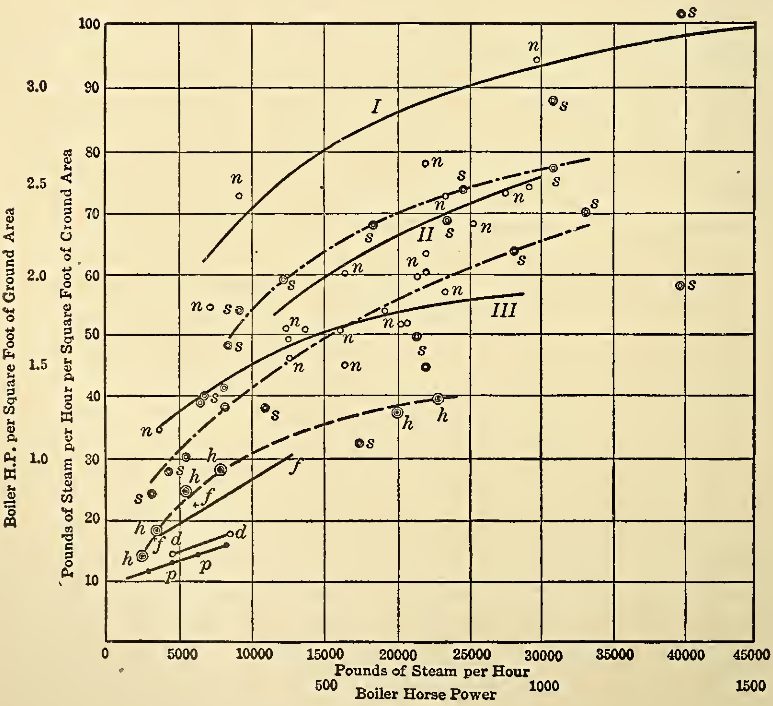


FIG. 12.

zinger, Z. V. d. I. 1912. Curve III gives the pounds of steam and boiler horse-power per square foot of ground area for boilers of the horizontal tube type in sizes up to about 1 000 h.p., based on a number of German installations.

According to this chart, a single boiler of 900 h.p. would give about 1.85 horse-power per square foot of ground area. Comparing this with the data of Table 1, it is found that the Type A requires 0.392 sq. ft. per h.p., which is equivalent to $2\frac{1}{2}$ h.p. per sq. ft. Similarly, the Type B gives about 1.6 h.p. per sq. ft. of ground area and the Type B_2 about 2 h.p. per sq. ft. of ground area.

Fig. 12 may be used in preliminary calculations to estimate floor space for a horizontal tube type boiler. Where a number of boilers are to be used, space must also be allowed for alleys, unless boilers similar to Type A are used.

DISCUSSION.

Mr. Hunter. Mr. Hobein, we would like to hear from you, as you are familiar with most of the types of boilers shown on the screen.

Mr. Hobein. I do not know that I have anything to say regarding the paper. It seemed to be very clearly presented. The horizontally baffled boilers saving in space it never occurred to me before to look at in this way. From the figures presented the matter is very clear. It certainly is quite a proposition in these days, when plants are built in the large cities, and the real estate forms such a large percentage of the cost, to keep the size of the boiler room down; and particularly nowadays, where the boiler room far outstrips the size of the prime mover room, the question of floor space for boilers is a very important one. One of the greatest problems nowadays, where the prime movers are in the form of steam turbines, and so much power in such a small amount of space, is to find room for the boilers to generate the steam for the turbines; and the study of the question of floor space for boilers is very timely and very interesting indeed.

Mr. Hunter. Has any other member anything to suggest?

Mr. ———. I wonder why it is that the size of boilers in power plants is usually about 600 h.p. It seems most plants built nowadays have boilers of that capacity, although in Detroit they have one about 2 000 h.p. It is quite a change from the old standard.

Mr. Meier. That was one of the types I showed there.

Mr. Hunter. Type C-2 was the type that was installed in the Detroit plant.

Mr. Meier. I noticed, when I got to looking over the bids on this particular letting, that everybody had bid on 9 000 or a little over 9 000 sq. ft. of boiler surface. The difference was so great in the floor space for different units that I thought it would be an interesting paper for that reason. The former gentleman, Mr. Hobein, said something about the turbine room being so small. It was interesting in the plant from which we took these figures that the turbines really took more room than the boiler plant would have if they had been able to install it without aisles, but on account of the coal bunker space and the space for the engine room, it would have made an egg-shaped building, so it did not, in that particular case, make so much difference.

Mr. ———. In figuring that floor space, as I understand it, the firing aisle was taken into account, but at the rear of the boilers it was assumed the soot blower would be used, so that nothing more than a normal alley to get at the blow-off was figured in at the rear. Is it the case that the soot blower is always such a success that you do not have to figure an aisle at the rear for blowing out?

Mr. Meier. I might say that that question was more or less anticipated, and 100 per cent. of the floor space was added to allow for the aisle and space to get behind them and in front of them. All of that floor space was figured over the actual floor space taken up by the boilers.

Mr. Hunter. The installation of boilers is a very important subject and should get a great deal of consideration from the designing engineer. I am sorry we do not give it as much attention as we ought to. Mr. Meier did not state just what capacity it was possible to get out of some of these boilers, but in most power stations to-day we are figuring on getting from 250 to 300 per cent. rating with forced draft.

Mr. Meier. That was the specification under which this letting was made. Every boiler had a guarantee of 200 per cent. overload.

Mr. Hunter. That is quite possible in a Heine type boiler. Our speaker was modest in not telling the names of the boilers, which might have been of interest to us, but being associated with the Heine Boiler Company I presume he did not want to call attention to their boiler, which was Type A, with which we are very familiar in this locality. With that type of boiler on test we have been able to get as high as 260 per cent. rating. This,

of course, requires a good grade of coal and a good draft over the fire bed. The only thing that is likely to cause trouble with the higher rating is the quality of feed water, which must be free from oil and scale-forming matter; otherwise we are liable to get blistered tubes.

The operation of the boiler room, in my mind, requires as much care and attention as does the design, especially when one stops to think that 85 per cent. of the total cost of operating a central station is expended in the boiler room. In a large central station, such as I am associated with, the average person, and even most engineers, do not appreciate the fact that only 15 per cent. of the total cost of generating electricity is expended in the engine room, but this, however, is a fact. Consequently, where engineers are expected to bring their over-all cost to the lowest figure, one will readily see that a good deal of time and energy must be spent in the boiler room, and upon the most efficient way of burning the coal, which in itself is about 65 per cent. of the total cost.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 15, 1913, for publication in a subsequent number of the JOURNAL.]

METAL MINING.

By Ervin W. McCullough.

[Read before the Civil Engineers' Society of St. Paul.]

Metal mining covers such a broad field that I can give you only a few general ideas in the time allotted to me. I will lay before you a short historical sketch of the mining industry in the United States and my opinion of its importance in shaping the destiny of the nation.

Metal Mining.

Few people realize what has been and is being done by the mining industry to advance our nation. Thousands of miners toiling deep in the earth's strata are lost to sight and generally forgotten by the public, until a Cherry Mine fire sacrifices such a number of lives as to appall the community and direct attention to the work of the human mole.

The mining industry is the foundation of all civilization; it is the basis on which all others must rest. The nation that has the greatest output, or that can control the production of precious metals, is the most potent factor in shaping international affairs.

Metal mining in North America began with the discovery of precious metals early in the sixteenth century and its history during the period of Spanish activity in Mexico, and what is now Texas, Arizona and New Mexico is full of romance and interest. These small beginnings grew rapidly to great importance, and were directly responsible for the colonization and development of the region farther north. The subsequent history of the territory now comprising the United States is a record of development of resources with mining always in the lead.

No nation has made material advance in civilization without possessing or controlling mineral wealth, and all nations thoroughly appreciate the importance of acquiring territory rich in minerals, especially the precious metals. In the deliberations of our government concerning the purchase or annexation of new territory, the fact that it contained valuable mineral deposits was always a factor in hastening or closing the negotiations. This was the case in the Louisiana Purchase and particularly so in the annexation of California.

Prior to the discovery of gold in California in 1849, gold mining in the United States was confined largely to the Southern states, Virginia, North and South Carolina, Georgia and Alabama. The last half of the nineteenth century witnessed the growth of a great gold and silver mining industry in the Western states, an iron industry of stupendous proportions in the Lake Superior region, and lead and zinc in the Mississippi Valley. The greatest development of our mining interests, like the greatest development of the country itself, has taken place during the past few decades. This is shown by the fact that the total value of the mineral product of our country has grown from about $370 000 000 in 1880 to over $1 990 000 000 in 1912. This means that while the United States was expanding on the surface of the earth, it was also expanding underground.

If we fail in an appreciation of the extent of the mining industry, we are equally at fault in failing to recognize the influence it exerts on our development. Wherever the prospector leads, civilization follows as a natural result; California, practically unknown in '48, is now in the front rank of the states of the Union both in population and wealth. From California the pioneers passed to the north and eastward, penetrating the territories of Washington, Oregon, Montana, Nevada, Utah, Arizona and New Mexico, developing trade, and sending out a stream of gold and silver which increased the wealth and importance of the United States as a whole and placed it among the powers of the world. The exploitation of the iron and copper ores of Michigan and the iron ores of Minnesota was largely responsible for the advancement of these states and for the development of our lake marine. The "New South" also owes its present advanced position more to the development of its mineral deposits than to any other feature. Special mention may be made of the copper deposits of Tennessee and the iron of Alabama.

The first effect of the discovery of gold in California on the handful of residents and the new arrivals was the abandonment of everything in a mad rush for the "diggings." Soon the incoming stream of gold seekers was offset by the large numbers who, discouraged by hardship and failure, gave up the search to engage in farming and cattle raising. Thus California gained a large agricultural population. Not only did the more venturesome of our own people flock to the Pacific, but thousands upon thousands of emigrants from the Old World made their homes in the West. Comparatively few stayed in the mines, the majority spreading northward and eastward to engage in agricultural

pursuits. Gold has also served as the great magnet to populate Alaska. Its floating population in search of fortune discovered the agricultural possibilities of the country, and now our so-called "frozen waste" is supporting a permanent farming community.

What language would have resulted from a natural mingling of the different races on the Pacific coast, had not gold been discovered, is a question well worth considering. It would probably have been a mixture of the pure Castilian and the Indo-Spaniard with the western pioneer, the Kanaka and the Mongolian. Social and educational standards would have been low; industrial progress backward and lacking in the enterprise that is distinctively American. The flood of well-educated people from the Eastern states prevented this by giving shape and direction to public affairs, and by impresing American ideas on the institutions of the country. In the Northwest, Oregon and British Columbia in particular, a trade lingo was established between the Hudson's Bay Fur Company and the aborigines, known as "Chinook Jargon." This language spread rapidly but was checked and almost wholly wiped out by the influx of more educated people drawn thither by the discovery of gold.

Another effect of gold and silver mining is to create new wealth, or purchasing power, and to open up new avenues of industry and trade. It has the same effect on finance, trade and commerce as steam has on locomotion. Trade and commerce, being merely the exchange of commodities, do not create new wealth, but merely concentrate existing wealth; i.e., finance, trade and commerce do not add to the stock of bullion; they merely enhance the value of property and merchandise and extend credit on business transacted. Any party of miners producing new gold from the earth does more good to the community than does all the trade of London and New York, because the gold so raised becomes an immediate addition to the working capital of the country by affording additional means of extending its credit and securing its liabilities. The continuous production of gold has become a *necessity* to the monetary institutions by whose aid trade and commerce have grown so rapidly, and we may reasonably hope that through the application of scientific principles, close economy and the coöperation of mechanical, civil, electrical and chemical engineers, the present generation of mining and metallurgical men will conserve our mineral resources and insure to successive generations their proportion of abundance and prosperity.

The production of metals has given an immense impetus to all manufactures, arts, sciences and learning. Take away the minerals and all modern manufacture would become impossible. The railroad would become little more than a suggestion for economical transportation without the possibility of substantial rails, bridges, cars or locomotives. The production of these and the tools used in their creation are in turn dependent on the metallurgical processes which transform the ores, fuels and fluxes into metal of commercial shapes. The development of these processes has encouraged the further exploitation of mineral deposits in such a manner and of such a magnitude as to supply satisfactory raw materials at a low cost.

The increase in gold production which caused the extension of trade and commerce resulted in a demand for better transportation facilities for the growing army of miners and traders, and the resulting volume of supplies. Gold being the recognized standard of value, the sudden increase in the medium of exchange brought about a decided disturbance in relative values. High prices resulted, stimulating production and opening new markets for exchange, with enlarged facilities for effecting them. In the twenty years following these urgent demands upon American commerce, the following events are chronicled, all the result of development of gold mining in California:

A new city was founded on the Pacific Coast, San Francisco.

Steamship lines were organized to connect New York with the Pacific.

A railroad was built across the Rocky Mountains.

A submarine cable was constructed across the Atlantic.

A railroad was built across the Isthmus of Darien.

Direct steam communication was established between the United States and the Far East, Japan, China and the East Indies.

The interdependence of mines and railroads is also shown in the mines of Butte, which send their ores to Anaconda (26 miles at 14 cents per ton) or to Great Falls (170 miles), where advantage is taken of the water power. Another instance is the shipment of copper matte from Tennessee to the heart of Mexico, where it is used to collect gold and silver from the "dry ores." The black copper is returned to the United States for refinement and separation of the gold and silver content. Again the Globe district, Arizona, languished for want of sulphur and iron flux, but the railroad issued a low tariff which brought in pyrite from distant districts. As a result, the production of copper rose rapidly to three million pounds per month.

The railroad is merely used as an illustration. Similar statements can be introduced to show the primary dependence of all, or nearly all, of our industrial and commercial advancement upon the mining industry.

When one notes the drills penetrating the hard rock, or the locomotives traversing the low, narrow drifts, both operated either by electricity or compressed air, generated at some distant point, the incentive to the engineer becomes apparent. Other developments in the mechanic arts stimulated by the mining industry are the dip needle, the prospecting drill, the sinking pump, the steam winch, the crushers, the chutes and the tram cars; the framing of shaft-sets, mine timbers and head-frames; the conveyance of steam, water, air or electricity for power in hoisting, tramming, pumping, etc.; the rails, cars and loading bins; the shipping and receiving docks for ore, and the vessels built for its transportation.

One seldom stops to consider the relation of metals to learning. The advancement and spread of learning which followed the invention of the printing press by John Gutenberg, about 1450, was dependent on the metal used in the movable type. By means of this new process the precious works of the ancients were preserved, the new thought of the Reformation was spread broadcast, and the price of books was reduced four fifths. The dependence of science upon mining is illustrated by the production of radium from pitchblend. Without minerals Mme. Curie's discovery would have been impossible.

To summarize: The mining industry has been responsible for the opening up of new territory, the development of agriculture, the unification of our language, the creation of new wealth, the growth of manufactures and the advancement of the arts and sciences as well as the extension of trade and commerce. But it is only when one descends into the mines and notes the great chambers dug in the earth, the quantities of timber placed to support the roof or hanging wall, the massive pumps which elevate enormous volumes of water from great depths, and the powerful hoisting and ventilating appliances, that the magnitude of the mining industry is truly appreciated.

In order to bring to your attention the unusual opportunities for engineers in our own state, I shall summarize briefly the situation in Minnesota, the greatest iron-producing district in the world.

Minnesota has a world-wide reputation as an iron ore producer. One county in this state produces over 60 per cent.

of the iron ore produced in the United States. The industry may be said to have commenced in September, 1884, with the completion of the railroad to Tower on the Vermilion Range. The discovery of the Missabe Range and its opening in the early nineties gave great impetus to iron mining.

The Missabe Range commenced shipment in 1893 with approximately 600 000 tons for the year. In the same year the Vermilion shipped 800 000 tons. In subsequent years Vermilion shipments have ranged from 900 000 to 2 000 000 tons, while Missabe shipments have increased by leaps and bounds to over 28 000 000 tons in a single year.

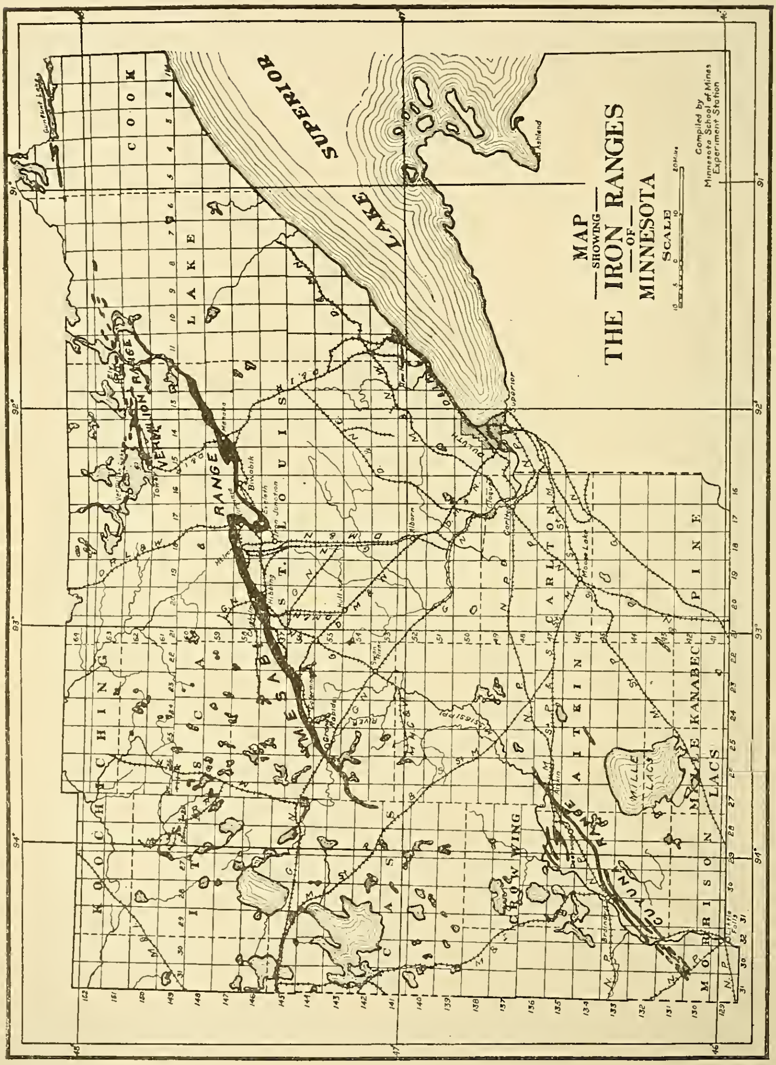
The next forward step was the opening of the western Missabe range and the commencement by the Oliver Iron Mining Company of ore-dressing experiments on the sandy, low-grade ore of that district. The result of these experiments is seen in a huge concentrator or washing plant at Coloraine that has been operated since September, 1910. The daily output of this plant is 10 000 or more tons of merchantable sandy ore. This experiment has demonstrated the commercial availability of the vast bodies of low-grade sandy ores. Another concentrator was constructed at the International Harvester Company's Hawkins mine.

It is estimated that over 85 000 people in St. Louis County are directly dependent on the iron mining industry. About 20 per cent. of this number represents the population connected with transportation, outlying exploration, etc., the balance being the resident population of the two ranges.

In 1910 there were 108 mines in operation, employing 17 613 men, at an average wage of $2.65. The ore shipments for the year aggregated 31 245 375 tons. One mine alone produced nearly 3 375 000 tons. Another one, 2 250 000 tons. Five mines produced over one million tons and a host of them from a half to a million tons. Incidental to the work of mining, 26 000 000 cu. yd. of overburden was stripped.

The total shipments to date from both ranges exceed 275-000 000 long tons. For the year 1910 there was reported to the Minnesota Tax Commission over one and one-third billion tons of discovered ore, — exactly 1 347 596 291 tons. The mining districts are situated from seventy to one hundred miles from the shipping ports on the Great Lakes. Three railroads handle the immense tonnage produced. In 1910 their aggregate mileage was 700, and their aggregate equipment comprised 16-725 steel ore cars and 230 engines.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 15, 1913, for publication in a subsequent number of the Journal.]



STEAM RAILROAD ELECTRIFICATION.

By Chas. P. Kahler, Member of the Utah Society of Engineers.

[Read before the Society, June 21, 1913.]

The transportation problem has been a very important one to mankind from the earliest times and has always received a great deal of attention from all classes of society. The use of horses, camels, elephants and other animals for transportation on land, and of ships on water, is mentioned in the history of the very early times, and the question of improving methods of transportation, especially by shortening of distance between different points, was given much thought at a very early date. The search for a shorter route from Europe to India than the camel caravan route via the deserts of Asia, or the sea route via the Cape of Good Hope at the south end of Africa, led to the discovery of America. The construction of the Suez Canal was in order to improve water transportation by shortening distances, and the present work on the Panama Canal has a reduction in distance as one of its objects.

Railroad men have not been backward in studying means of improving railroad transportation, as is shown by the many improvements which have been made since the introduction of the steam engine in transportation. The cut-off of the Southern Pacific over the Great Salt Lake, which was done during the administration of the late Mr. Harriman, will give an idea of the way modern railroad officials attack the problem of improving the railroad facilities. By this cut-off, about 50 miles of distance was saved in a total distance of 150 miles, and the grade by the new route was very light, while it was necessary to haul trains over two mountain ranges by the old line, which will give some idea of the value of this improvement. However, the use of electric power as a means of transportation has to date been very limited. It is my intention now to give briefly a general idea of the apparatus and equipment needed to operate a railroad by electric power and to show the comparative cost of steam and electric operation, together with some of the improvements in railroad transportation which would result.

Street and Interurban Railroads: The introduction of trolley cars on street railways was the first use to which electric power

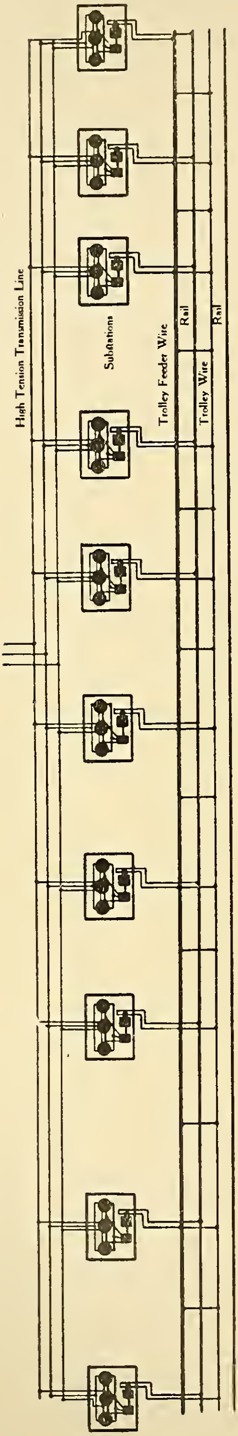


FIG. 1. 1500 VOLT DIRECT CURRENT SYSTEM

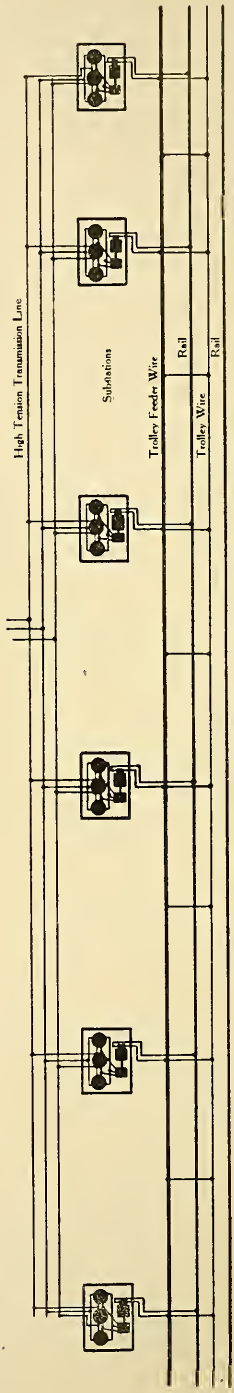


FIG. 2. 2400 VOLT DIRECT CURRENT SYSTEM

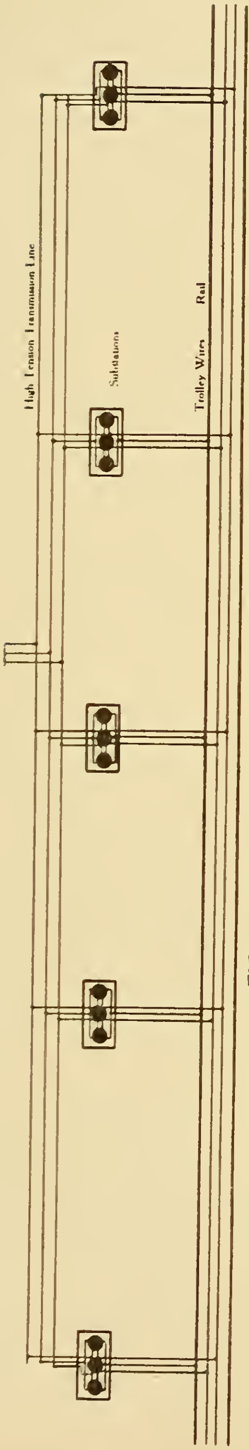


FIG. 3. 11000 VOLT THREE PHASE SYSTEM

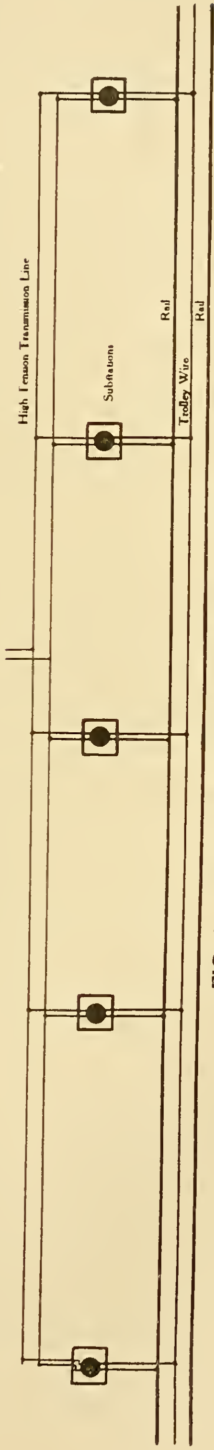


FIG. 4. 11000 VOLT SINGLE PHASE SYSTEM

was put in railroad transportation, and the series wound direct-current motor, operating at from 500 to 600 volts, soon became standard for this service. The next general use of electric power in railroad transportation was the building of interurban railways. The improvement in local railroad train service by the interurban trolley lines soon drew nearly all of the local passenger traffic from paralleling steam roads, the reasons being that frequent interurban cars could be operated at less cost than the infrequent local steam trains usually operated, and the electric railways could, and did, charge less fare. The electric cars could make frequent stops to take on and let off passengers and maintain as fast a schedule as the steam trains did with comparatively few stops. The fact that there was less noise and no smoke made the operation of trolley cars through the centers of towns unobjectionable and consequently they were more convenient than steam trains, which generally kept away from the town centers.

These are some of the advantages which enabled the electric trains to be so successful in getting local passenger traffic, and in fact the local passenger revenue, even with lower fare, soon became greater than the steam roads had obtained in the same territory with no competition.

Besides the direct-current motors, some of the interurban lines found it advantageous to use single-phase alternating-current motors on their cars, which were advantageous on account of the simple and low cost transmission system which they permitted.

Electric Locomotives for Steam Railways: Electric locomotives were first used to displace steam locomotives in heavy railroad work for some local cause, the most important of which was the elimination of smoke, especially in tunnels. During the seventeen years electric locomotives have been in use on steam railroads they have not only demonstrated their reliability, but even in their limited use they have shown that they can at many points handle the traffic on steam railroads in a more satisfactory manner than steam locomotives are now doing it. Their limited use in heavy electric railroad work at present is due to the heavy expenditure necessary for the electric equipment. But before discussing the economics of steam and electric railroads, the different systems or ways in which railroads are now operated by electric power will be briefly outlined.

Systems of Electrification: There are three general systems with more or less modifications used in electric railroad operation,

the direct-current system, the three-phase system, and the single-phase system. These are diagramatically shown in Fig. 1, 2, 3 and 4. Experience has shown that any of these systems, if properly installed, will be reliable in operation.

All systems would, for heavy trunk-line railroad work, distribute the power from the power plant by the use of high-tension alternating-current transmission lines; all have substations for converting the high-tension current into lower voltage current for the trolley wire. The direct-current system substations have transformers for lowering the voltage, and motor generator sets for converting the low voltage alternating current into direct current for the trolley wire. The single-phase and three-phase systems substations only have transformers for reducing the high voltage for the trolley wire, there being no need of motor generator sets, as on either the single- or three-phase systems the locomotives operate by alternating current.

All systems have some sort of contact line (trolley or third rail) for carrying the current from the substations to the locomotives. The low voltage direct-current system usually has third rail in heavy work, which is necessary on account of the quantity of current (amperes) to be collected. The highest voltage direct-current systems have an overhead trolley, which is safer than the third rail and permits the collection of enough current for a medium-sized locomotive with one collector at 2 400 volts, which is the highest voltage trolley yet tried on a direct-current system.

The single-phase system has a high voltage trolley, which in this country is usually operated at 11 000 volts for heavy railway work, there being a transformer in top of the locomotive which reduces the voltage so that it can be used in the motors, and also with the high voltage of the single-phase trolley it only requires a comparatively small amount of current to be collected to permit of operation of as powerful a locomotive as desired.

During the last few years there has been a rather warm discussion between the electric manufacturing companies as to which of these systems is best for railroad operation. This discussion probably did considerable good, as the numerous improvements on all the motors which resulted made it possible to obtain a locomotive equipped with any of these motors, which will be reliable in operation. For the same output, the single-phase locomotive is heavier than the direct-current locomotive, which is one of the arguments advanced by the

direct-current system advocates. On the other hand, the drooping characteristic of the tractive power of the direct-current motor at high speeds as shown in Fig. 5, gives the single-phase motor some advantages for general work.

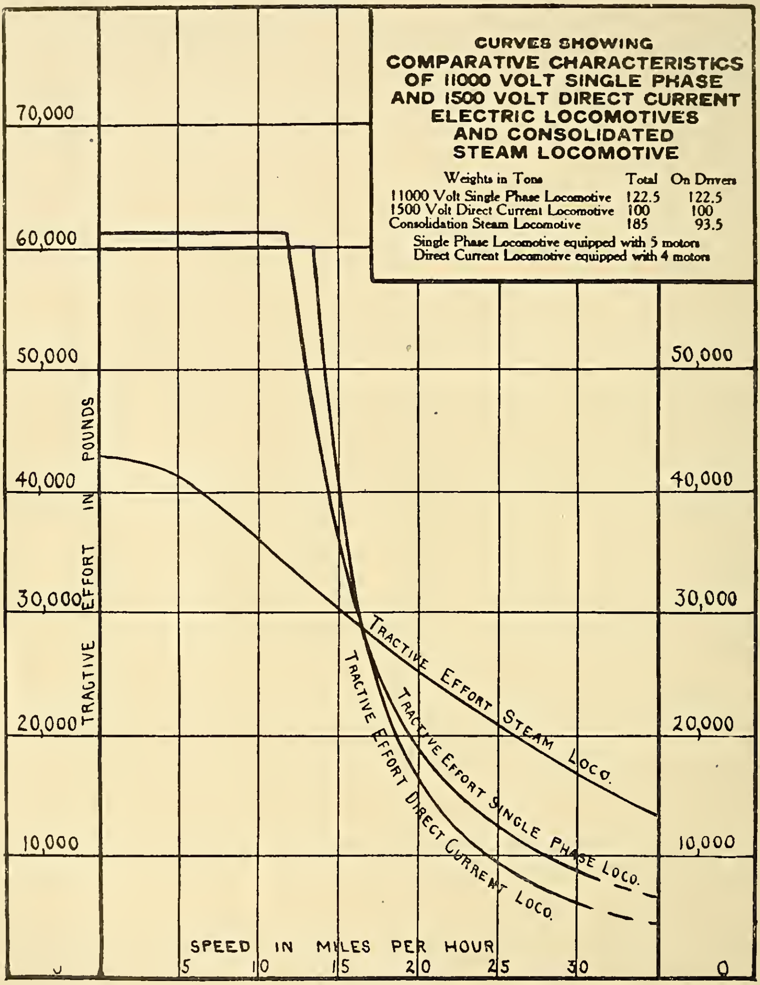


FIG. 5

One of the big differences between the direct-current and the other systems is the fact that the direct-current system requires more substations than the other system and that motor generators have to be used in them, requiring the necessity of permanent attendants; whereas the single-phase and three-phase

system substations, which only have transformers, require no permanent attendants, as they only need the inspection ordinarily required by transformers, which can be done by the linemen.

Another difference is that heavy trolley feeder wires are required by the direct-current system, with the consequent heavy cost, which is not the case with the other systems.

In the past, considerable trouble was experienced with the motors of all systems, but the many improvements, as, for instance, the introduction of the inter-poles which made the operation of comparatively high voltage direct-current motors possible, the improving of details which made good commutation possible on the single-phase motors, the use of forced draft which reduced the locomotive cost, the proper consideration of gearing, etc., have made reliable motors available for railroad work with all three electric systems.

However, the system as a whole has to be considered, and the relative advantages and disadvantages of the different systems compared, if the proper system is to be correctly determined.

The three-phase system has nearly all the advantages which the single-phase system has, as far as transmission system and substations are concerned, but in its present state of development is not suitable for general railroad work, on account of the constant speed characteristic of the three-phase motor and on account of the difficulties and expense necessary for operating at high speed and of doing switching work with two high-voltage trolley wires.

To bring out the essential difference between the different systems, the diagrams on Fig. 1, 2, 3 and 4, were drawn up.

Comparative First Cost and Operating Expenses by Different Systems: As a general proposition the cost of installing a direct-current system is admitted by all to be much greater than the cost of a single-phase system. Single-phase locomotives cost more than the low-voltage direct-current locomotives for the same output, but the difference in cost is not so great when the high-voltage direct-current locomotive is considered. On the other hand, the high cost of feeder copper and substations, even for the high-voltage direct-current system now proposed, much more than offsets the higher cost of the single-phase locomotives for long trunk-line work. The diagram given in Fig. 6, which is for an engine district a little over 150 miles in length, shows the comparative first cost of a 1 500 volt and a 2 400 volt direct-

current system and a 11 000 volt single-phase system. You will note that the items upon which the comparative first cost hinges are the trolley and feeder wires, the substations and the locomotives.

COMPARATIVE FIRST COST OF ELECTRIFICATION BY SINGLE-PHASE, 2400-VOLT DIRECT-CURRENT AND 1500-VOLT DIRECT-CURRENT SYSTEMS.

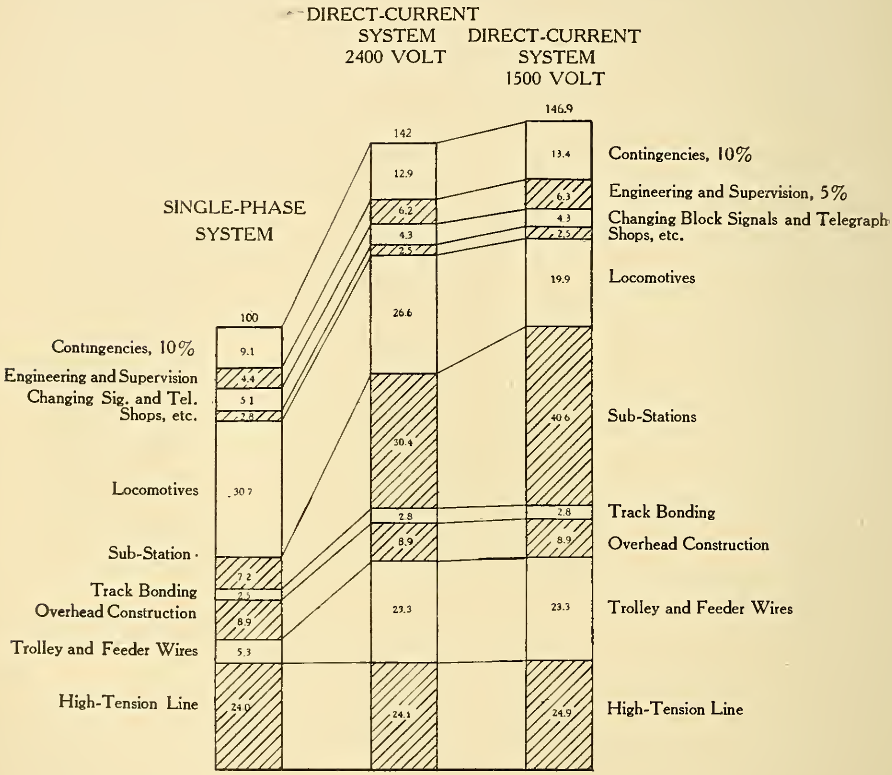


FIG. 6.

The diagram in Fig. 7 shows the comparative first cost of the three systems. Also the dotted lines show 5 per cent. interest on the cost of installation. The 2 400 volt direct-current system costs about 12.3 per cent. more and the 1 500 volt direct-current system costs 14.7 per cent. more to operate than the single-phase system, the influencing items being the cost of electric power, maintenance of locomotives and maintenance and operation of

substations. When 5 per cent. interest is added for the first cost, the 2 400 volt direct-current system would cost 18.2 per cent. more per year and the 1 500 volt direct-current system would cost 20.9 per cent. more per year than the 11 000 volt single-phase system.

COMPARATIVE MAINTENANCE, OPERATION AND DEPRECIATION EXPENSES BY DIFFERENT ELECTRIC SYSTEMS.

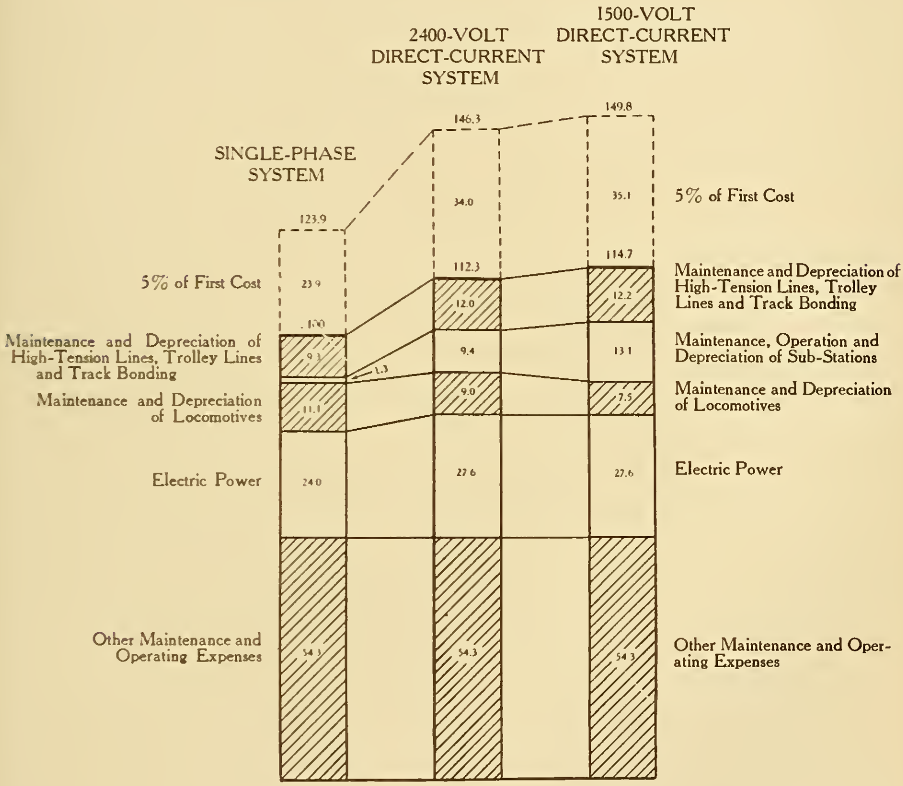


FIG. 7.

Mercury Arc Rectifier System: The adaptation of the mercury arc rectifier to high powers which has just been announced makes it possible to convert single-phase alternating current at any voltage into direct current. This will enable single-phase current from the trolley to be converted into direct current on the locomotive, making it possible to use the high-voltage

trolley with transformer sub-stations, which is admitted by every one to be the best and most simple system of transmission, and also permit the use of direct-current motors upon the locomotive, which are preferred by some. While it is a debatable question whether a mercury arc locomotive will be any more advantageous than the use of a straight single-phase locomotive in its present state of development, the fact that a direct-current locomotive can be used on a single-phase trolley system will no doubt settle the argument as to system, as the only points open to discussion will be the details of the locomotive, and experience will show whether the straight single-phase locomotive or the single-phase direct-current rectifier locomotive is most satisfactory and economic of operation. I am inclined to believe that there will be little hesitation in using the single-phase trolley system in the future.

Comparison of Steam and Electric Operation: As stated before, the past heavy railroad electrification work was only done on account of the smoke nuisance or some other such reason, and no direct financial return was expected on the cost of installation. However, the past experience with the electric locomotive has shown that it is qualified to handle heavy railway traffic as reliably and under some conditions more economically than steam locomotives.

Where conditions are favorable, it will be more economical to operate a railroad with electric locomotives than with steam locomotives, because the same tonnage could be handled by fewer freight trains, because the direct cost of train operation would be less, and because there would be an increase in the passenger earnings result, as it would be possible to operate a more frequent train service with frequent stops at less cost than the ordinary steam local passenger service.

The characteristic curves of a steam freight locomotive, a single-phase and a 1 500 volt direct-current electric locomotive for freight service are shown in Fig. 5. At low speeds the electric locomotives are able to exert the higher tractive effort, while at high speeds the steam locomotive is more powerful. However, the weight of the freight trains is governed by the tonnage which can be hauled over the ruling grades, which are usually short in length and where the speed is comparatively low. As the electric locomotives have a much higher tractive effort at low speeds than the steam locomotives, they can, of course, haul heavier loads over the grades which govern steam operation. There would, of course, be a large saving if very much reduction

could be made in the number of trains. Steam railroad men, now that the steam locomotive has about reached its maximum size, endeavor to accomplish the same thing by grade reduction work.

The direct cost of electric train operation would be less than steam train operation, as there would be no water or fuel stations to maintain; the locomotive repair cost would be considerably reduced, as there is no boiler or fire-box on electric locomotives

COMPARATIVE OPERATING EXPENSES
FOR STEAM AND SINGLE-PHASE ELECTRIC OPERATION.

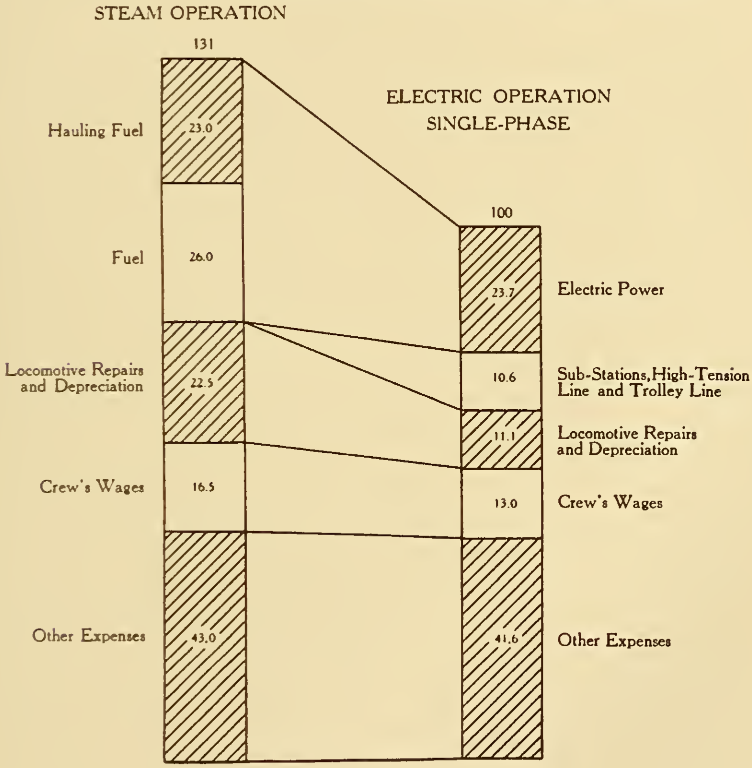


FIG. 8.

to take care of; the engine-house expenses would be less, as there would be no boiler washing, cleaning of fire boxes, starting of fires, etc., with electric locomotives; and the fuel expense would be reduced, as it takes only about half as much coal to generate power in a steam plant for the electric operation of a railroad as

would be used on steam locomotives in the same service. In addition, the cost of hauling locomotive coal over a railroad's own track from the mines to the fuel stations is a large amount and would be unnecessary or at most greatly reduced by electric operation.

On the other hand, the maintenance and operating cost would be considerably increased on account of the maintenance of the electric lines and substations necessary for electric operation. But this increase would in many cases be small compared to the decrease in expenses.

Return on Investment: For the engine district used for illustration above, steam operation would cost about 31 per cent. more than electric operation, as shown by the diagram (Fig. 8). The first cost of electrification would be somewhere near $23 000 per mile of line, complete. Consequently, the saving in expenses on account of electric operation would have to be $1 150 per year per mile of line if 5 per cent. interest was to be earned on the investment; or, in other words, if the annual expenses amounted to $3,710 per mile the reduction (31 per cent.) on account of the substitution of electric locomotives for steam would earn just 5 per cent. interest on the investment. In this particular case, the annual maintenance and operating expenses amounted to about $7 000 per mile of line, and thus a total of about 10 per cent. earning would be had on the investment for electrification. As the traffic increased, of course the return on the investment would increase.

Another source of revenue which would result from electrification, in addition to the reduction in operating expenses, would be the increase in passenger revenues. Thus by increasing the number of passenger trains by operating a number of electric motor cars which could maintain, on the good road beds usual on most steam railroads, a higher schedule speed with more frequent stops than would be possible with steam trains. It was estimated for this case that an increase in passenger revenue of $2 000 per mile of line per year could be obtained by increasing the number of passenger trains, which would raise the annual operating expenses about $800 per mile, leaving a profit of $1 200 per year, or about 6 per cent. of the total cost of electrification. The total return on account of electric operation in this particular case would thus be about 16 per cent. on the total investment. Attention is called to a particular case in order to make the general economic problem clear.

Density of Traffic: Until recently it was supposed that electrification would only be warranted on steam railroads with very heavy traffic, as, for instance, on some of the four-tracked lines in the East. However, it is now known that conditions at many places will make the electrification of many lines with only medium traffic warranted, and that conditions are often favorable for electrification on fairly light traffic lines, especially in localities where electric power can be purchased at low cost, either on account of low development cost water-power plants, or low fuel cost.

Conclusion.

I have tried to give a general idea of the electric railroad situation and the various factors entering into same, with special reference to the electrification of steam railroads. The diagrams given, while applying to a particular case, were used to bring out the governing points and show the interrelation between steam and electric railway operation and between the different electric systems.

While there has been considerable discussion during the past few years as to the proper electric system to use, on account of the keen rivalry between the electric manufacturing companies, which has in some instances confused the railroad people and tended to prevent them from doing any electric work, the facts are now beginning to be fully understood by railroad men generally and the question of system is not now considered a serious obstacle. This is especially so on account of the promising tests made with mercury arc rectifier locomotives, which will permit a locomotive equipped with direct-current motors to be operated from a single-phase trolley.

There is no question but that a high voltage trolley is absolutely necessary where the distances are of any length. The single-phase system in this country usually operates with a 11 000 volt trolley, while the highest voltage of any direct-current system actually operating is 1 500 volts. The 2 400 volt system now being installed on the Butte, Anaconda & Pacific Railway, if it is successful in operation, as expected, appears to me a step in the right direction, but I hardly think the direct-current system at this voltage will be very much used. It appears to me that upward of 4 000 volts at the trolley will have to be used if the direct-current locomotive is to compare favorably with the single-phase locomotive.

The locomotive on all systems is probably where the most radical improvements in electric railroad apparatus will be made in the near future. The great problem now is to transmit the power from the motors to the locomotive drive wheels. The question as to whether gearing, side rods or a combination of both should be used is now an open question.

COMPARATIVE POWER CONSUMPTIONS OF A RAILROAD, ELECTRICALLY OPERATED BY A SINGLE-PHASE AND A DIRECT-CURRENT SYSTEM.

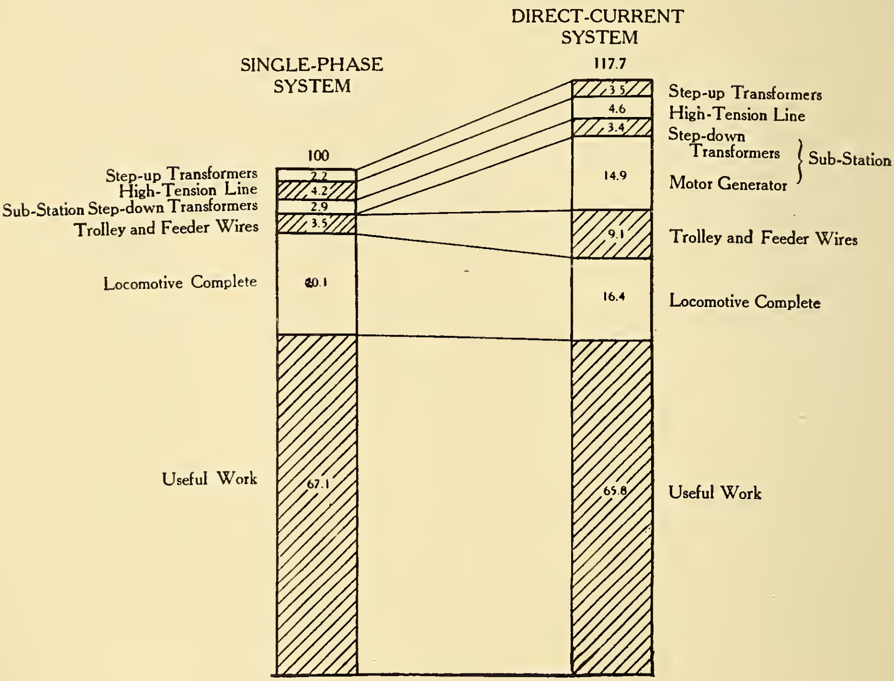


FIG. 9.

In the diagram of comparative operating costs of steam and electric railroads, no credit is allowed the electric locomotive on account of the less damage to the track by reason of lighter weight. This was done to simplify matters and bring out the most important factors.

The example taken to illustrate the various factors which enter into the first cost and operating expenses of the different systems of electrification, shows that the single-phase system

would be by far the most economical to install in this instance. However, every case should be worked out on its own merits. In most of the steam line investigations I have made, the single-phase system has shown to be more economical than the direct-current system, where the distances have been over 25 or 30 miles, even with as high as 2 400 volts at the trolley wire.

The high first cost of the direct-current system is usually a very serious objection to its use for steam railroad electrification. This comes out very prominently when a long line is considered. If a single-phase system would cost $50 000 000, a direct-current system would cost $71 000 000, if the percentages worked out the same as example taken above.

In considering the proper system for operating an electric interurban railroad where light motor cars are to be operated, it will be found that the single-phase system will not show up as advantageous, when compared to a direct-current system, as is the case when the electrification of a steam railroad operating heavy trains is considered. The equipment, weight and cost favor the direct-current system, and as the train weights are usually light on an interurban railroad, the advantages resulting therefrom are sometimes great enough to make a direct-current system the proper one to install. However, for most of the cases I have investigated, the single-phase system has shown up better than the direct-current system even for interurban work, except where it is necessary to use both alternate current and direct current with the same equipment, as where interurban railways have to operate over street railway tracks with low-voltage direct-current trolley wire.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 15, 1913, for publication in a subsequent number of the JOURNAL.]

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A LAND MAP OF THE WORLD ON A NEW PROJECTION.

By B. J. S. CAHILL, A.I.A., F.R.G.S.

[Read before the Technical Society of the Pacific Coast, October 11, 1912, and discussed before the Association of Scientific Societies.]

ON a previous occasion, when I enjoyed the privilege of addressing you, I spoke of the plans I made for San Francisco's Civic Center. It is now over thirteen years since I made the first plan to improve the city of San Francisco. I began the movement single-handed and was looked upon at the time as an impossible dreamer. Nevertheless, the actual plan which I drew in 1904, my second scheme, the one I described to this Society, has now been adopted almost exactly as I planned it eight years ago. With some modifications rendered possible, though not in my opinion desirable, by reason of the destruction of the City Hall, this plan is now being actually carried out at a cost of some ten millions of dollars. This fact is mentioned for two reasons bearing on the subject in hand. In the first place, the initial failures following any great endeavor — and they are inevitable — have the effect on one's energies that obtains in the world of physics. If one's efforts are baffled and suppressed in one direction, they seek vent in another. From the failure of my Civic-Center plans in 1905 dates the beginning of my activities on the new map projection. Then, secondly, if one's ideas finally triumph and one lives to see victory follow defeat, the result is a moral strengthening of purpose and an access of new courage and confidence in fresh fields of endeavor. I am therefore emboldened to say to you, not only with confidence

but with conviction, that this new projection which I shall show you to-night will, before many years, be in use in the text-books, atlases, maps and encyclopedias of the world. Since I have spoken of city planning, let me quote to you a very notable utterance of the late Daniel H. Burnham, the architect, in his concluding remarks before the London Town Planning Conference of 1910. He said, "Remember that a noble logical diagram once recorded will never die; long after we are gone it will be a living thing, asserting itself with ever-growing insistency, and, above all, remember that the greatest and noblest that man can do is yet to come, and that this will ever be so, else is evolution a myth."

In presenting my subject I shall first point out the inadequacy of the projections now in use; I shall then explain the principles of the new projection and conclude by showing some of the uses to which it can be put.

I.

At the very outset I want to state that when speaking of projections I have in mind, of course, projections of the whole world, and my criticism of existing maps is wholly confined to world maps. Regarding regional maps, marine charts, geodetic and topographical surveys, it is only necessary to say that this, the main part of the science of cartography, has been brought to the highest pitch of perfection by the joint labors of many of the world's greatest mathematicians. Needless to say, I make no claims to improvements here. But the fact that map making has been almost wholly in the hands of theoretical scientists has resulted in certain abuses which I think engineers can very well appreciate. A bridge designed wholly from the mathematician's standpoint may not be practical or desirable from the viewpoint of those who intend to use the bridge by going under it on water, or over it on wheels. Just exactly why ultra-mathematical world maps are unsatisfactory, we shall see further on in detail.

The earliest projections used by the Greeks concerned themselves with a hemisphere only. A point of light is conceived at the center, casting a shadow through the surface of the hemisphere on to a tangent plane. This is the gnomonic projection, invented by Thales. (See Fig. 3, 4, 9 and 15.) When this point of light is moved away into the plane of the completed sphere, — that is to say, twice as far from the point of tangency

as the gnomonic, — the resulting projection is called the stereographic. (See Fig. 1 and 2.)

A third method moves the point of light to an infinite distance, so that lines of projection are all parallel. This is the projection generally used by architectural, engineering and mechanical draftsmen. (See Fig. 5, 6 and 11.) Hipparchus invented both of these. A fourth projection of this class was proposed by La Hire in 1701 and perfected by Lambert, the greatest, perhaps, of all modern projectionists. The point of light is here supposed to be at such a distance from the surface of the completed sphere that the radius of the shadowed disk is exactly the same length as the arc of a quadrant. (This distance is $\sqrt{\frac{1}{2}}$ times radius beyond the surface of the sphere.) (See Fig. 7, 13, 23, 24 and 25.)

In these projections, excepting the first mentioned, the whole world must be shown in two disks. Fig. 1, 2, 5, 6 and 7 show how different the results are. They are all drawn to the same scale, yet the half of the world shown looks different in each.

The gnomonic projection cannot show the whole world on two disks because they would have to be infinite in size. So, instead of 180 degrees of arc, we show only 90 degrees; the tangent planes are made square and six in number. In this projection the world becomes a cube. Thales, therefore, who lived several centuries before Christ, was the first "cubist." (See Fig. 3, 4, 9 and 15.)

In the next type of projection the shadow is thrown on to a tangent cylinder or a tangent cone. The cylinder, or cone, is then developed or laid flat. (See Fig. 11, 12, 13, 14, 17, 19 and 49.)

The point of light may be, as in the other projections mentioned, central, or at an infinite distance, or at varying points between.

In all these methods the plane of projection can be conceived as a secant, as well as a tangent plane. In each case also the plane of projection may be parallel to the equator or the pole or any horizon between.

It has been noted that the orthographic and stereographic projections can only show a hemisphere at a time. The gnomonic must show less, preferably a third, and the globular may show more, conveniently a third. The cylindrical method shows the whole world on one rectangular plane, with parallel meridians. The conical method may also show the whole world

on a fan-shaped plane with meridians converging to one pole extended. This method may also be used on one hemisphere at a time, showing the northern and southern hemispheres, for example, as two fan-shaped planes of more or less obtuse or acute convergence, according to the high or low latitude of actual or mean tangency.

All these projections are in reality skiagraphic, made by casting shadows, and whether direct on disks, or by development on cylinder and cone, they all have one fault in common. *Their ultimate form or boundary bears no relation to the surface of the sphere or part of the sphere they represent.*

I wish to call attention to the curious relation between the forms generated in these projections; the sphere, whose surface is to be represented, and the cube, the cone and the cylinder. The three classic projections are based on these forms. The gnomonic projects the sphere on to the six sides of a circumscribed cube; the orthographic projects the sphere on to the two ends of a circumscribed cylinder; the stereographic projects the sphere on to the tangent bases of two inscribed intersecting right cones.

Now, curiously enough, in a complementary and reciprocal sort of way, we have a projection where the *side* of a cylinder carries the projected outlines of the earth, that is, Mercator's, and another where the *side* of a cone carries the outlines of the earth.

In other words, the modern conic projection is a sort of reciprocal of the classic stereographic, and the modern Mercator map is a reciprocal of the classic orthographic. In the first case, the base of cone and cylinder carries the shadowed imprint of the sphere's surface, the sides being blank. In the second case, the side of the cone and cylinder carries the shadowed imprint of the sphere's surface, the bases being blank. (See Fig. 9, 11, 12, 13 and 14.)

But the world is neither cubical, cylindrical nor conical, and none of these really artificial methods, although called natural, are of much all-round value to the geographer, although as practical diagrams for mariners the gnomonic is invaluable for purposes of steam navigation, and Mercator's for steering a course by log and compass. Both methods used on large areas show enormous exaggeration, Mercator at the poles and the gnomonic at the edges. (See Fig. 15, 17, 19 and 49.)

The stereographic and globular very much stretch the periphery of the map so that the edges are exaggerated, while

the orthographic preserves the peripheral distances, but distorts by overcrowding. Moreover, only two of these methods show the world in one continuous map.

Attention is called to the vital question of *scale* in these illustrations. The whole matter of map projections is vitiated by a very strange mixing of ultra-scientific scrupulousness in defining each separate projection with the most thoughtless, even ridiculous, carelessness in graphically illustrating these projections in comparison with one another.

We have seen that the various disk projections show a hemisphere with varying diameters. Thus, the orthomorphic projection shows a disk containing half the world exactly the same diameter as the sphere from which it is derived. Each gnomonic facet is a square of the same diameter, but only presenting one sixth of the earth's surface. The globular projection shows half the world on a disk whose diameter is half the sphere's circumference. In the stereographic projection the hemisphere is projected on a disk whose diameter is twice the sphere's diameter. An equal area hemispherical projection would show still another diameter, one that would make the disk's area equal to the area of the hemisphere it represents. (See Fig. 26.)

Now, in the ordinary accounts of projections, appended to geographies or atlases, it seems customary to show all these disks, which we have just seen to be of *different* diameters, all to the *same* diameter. I have here a learned treatise on Projections, published by the United States Government, under the heading: " Report of the Superintendent of the United States Coast and Geodetic Survey for 1880." The appendix, prepared by Chas. A. Schott, is supplemented with six engraved plates and a chart illustrating the subject of projection. The plates are all very carefully made. The first one shows four different projections on one sheet, yet all drawn exactly the same size, whereas in reality each of the four hemispheres shown would be different in diameter if they all four represented projections of the same sized sphere.

In a paper purporting to show " relative values " of various projections, such a blunder is absolutely inexcusable. It makes comparison impossible and gives the student utterly erroneous ideas of all the inherent attributes of the various projections so scrupulously described in the text.

It is a much more mischievous habit than that of the average map maker who puts all countries, states and continents so

that they fill the page of his book exactly, regardless of their relative size.

I wish to draw particular attention to this, because it seems to be characteristic of the ultra-scientific method of making world projections heretofore, viz., over-scrupulousness regarding the means of producing projections combined with an absolutely exasperating indifference as to the ends achieved. Theoretical considerations, in other words, have outweighed practical ones.

Of the single world maps now in actual general use, by far the best known are Mercator's and Mollweide's, shown in Fig. 19 and 20. Both of these are here shown drawn to the same scale. They are both portraits of Mother Earth as represented on a globe, the actual gores of which have here been peeled off by soaking in hot water, then dried and pasted side by side as you see in Fig. 18.

Here, then, we have the facts as to the land and water areas, although mutilated by being cut into gores. In the mind's eye, however, you can piece them together well enough to make a few comparisons. All the parts of the land shown in black on these fusiform sections are also practically devoid of distortion, as well as of exaggeration.

Before making these comparisons, however, I will say a few words about this elliptical projection called variously Babinet's homolographic or equal surface, Mollweide's or the Equivalent. The distinctive character of this important projection is, as its name implies, a proportionality of areas on the sphere with the corresponding areas of the projection. This projection consists of an ellipse whose major axis is the length of the equator and whose minor axis is the length of a meridian.

To begin with, the area of such an ellipse is *not* the same as the area of the sphere it represents. The surface of a sphere 8 in. in diameter is about 201 sq. in., but an ellipse whose major and minor axes are, respectively, the circumference and semi-circumference of an 8-in. sphere contains an area of nearly 248 sq. in., an excess area of nearly 25 per cent.

This projection is the same as Mercator's at the equator where distances east and west are correct. Distances on the parallels are also fairly correct towards the center of the map.

The central meridian also is correct as far as distances north and south are concerned, but each meridian east and west of the central one becomes more and more elongated by reason of the increasing curvature. When this curvature increases to the arc of a circle, as it does at 90 degrees of longitude, east and

west of the central meridian, we have a projection of a hemisphere whose extreme or boundary meridians already exceed their real length in the ratio of *pi* : 2, or 157 to 100, an excess of nearly 60 per cent. Where, for the sake of presenting the whole world in one ellipse, meridian after meridian is added to this already elongated arc until 90 degrees have been added each side in the form of two lunettes, we have piled the Ossa of elongation on to the Pelion of distortion until the boundaries of our map are bent and stretched to an extreme that reaches and overlaps the limit of absurdity.

This brings us back from our digression to a comparison of Mercator's and Mollweide's portraits of Mother Earth with her actual features as revealed in the gores of a globe when laid flat. (See Fig. 18, 19 and 20.)

The enormous exaggeration of Mercator's chart is best expressed by stating that if the north pole were on an island or the south pole on a lake ten miles wide, both lake and isle would have to be drawn 24 000 miles wide, the same as the whole equator.

The outrageous distortion of Mollweide's map is best realized by placing the east and west boundaries of the map back to back. We then see that what should be one vertical meridian — a straight line from pole to pole (equivalent to the minor axis on the ellipse) — is now expressed by violently curved and elongated lines equivalent to the entire periphery of the ellipse.

Expressed mechanically, it is easy to see that neither a pair of disks, a rectangle nor an ellipse can be accurately made to represent the covering of a sphere.

Projections of these forms, however, are universally used to show the whole or half the world on one map.

In the English-speaking world, Mercator's is more general; on the European continent Mollweide's obtains greater favor. It is obvious that before publishers will abandon either of these time-honored projections and scrap the many expensive plates on which they are engraved or lithographed, some very decided improvement must be offered which may reasonably be counted on as likely to be in universal demand by scientists, teachers and the public. To change the accepted maps of the world requires a great effort like a revolution in government or a reformation in religion. It is plain, also, that while the abuses or the inadequacy of the world maps now printed may be generally recognized and even deplored, there will be small chance for minor improvements, half-studied projections or unscientific compromises being generally adopted.

Thus the Van der Grinten projection (see Fig. 21) is, in a sense, a compromise between Mollweide's and Mercator's, with very much less distortion than the former and not so much exaggeration as the latter. It is a hybrid map in a sense, and, like other hybrids, does not inherit the virtues of its forbears. It cannot be repeated east and west like Mercator's, nor has it Mercator's angular accuracy so useful to navigators nor the rectilinear boundaries by which regional charts may be correlated or connected. Nor has this map the advantages of equivalent areas found in Mollweide's. Its circular form, moreover, is unscientific. For all that, its appearance marks a protest and is a valuable contribution to the movement inasmuch as it unsettles fixed acquiescence in the established projections and no doubt has prepared the world for a more rational one by at least drawing attention to the need of it if nothing more.

The fact, moreover, that the author of this new projection was enabled to secure patent rights is not without interest.

I come now to consider another school of world-map projections not developed from any of those heretofore mentioned. The new type calls for all of the principles and practices developed in making the skiagraphic maps whether direct or on to developable surfaces of cone and cylinder; also the mathematical analysis necessary to construct maps by development and plotting used for obtaining a high degree of accuracy in the making of regional maps. Of such are Bonne's, Flamsteed's and Hassler's polyconic projections. Of these, Flamsteed's is similar to Mollweide's; and Bonne's and the polyconic are admittedly quite unsuitable for single maps of the entire world. (See Fig. 22 and 48.)

The latest type of world map projections bears somewhat the relation to the classic and the mathematical projections of the ancients and moderns that science based on experiment and applied to practical ends does to synthetical and analytical science in the abstract. I merely wish to suggest an analogy. The older scientific attitude is theoretical and ideal. The Greeks were mentally averse to experiments. The next trend after the synthetic or generalizing is towards the analytic or specializing. The third and final attitude of the mind is to drop ideal and comprehensive theories on the one hand, to withdraw from hair-splitting details on the other, and to look to the actual facts as we find them by experiment and to apply our knowledge so obtained to the direct needs of humanity and the hour.

But it must not be forgotten that the large view of the first method and the grasp of detail developed in the second will both be needed in the final compromise.

The older projectionists conceived the world geometrically as a sphere, all parts of which were of equal interest. The most recent school of projectionists takes cognizance of the actual shape of the land and water as they are distributed over the globe. And this suggests that the earliest scientific attitude towards any problem is necessarily theoretical, seeing that all the facts are often unknown until a comparatively late date.

It is only recently, in a scientific sense, that we have learned the facts regarding the shape of the continents, and very much more recently, that is to say, in this very generation, that the boundaries of the world's colonies on the dark continent, for example, have received definite delimitation. Therefore, while the outlines of the water-world have been known for over three centuries, the outlines of our land-world have only been established three decades.

Mercator's chart admirably serves the purposes of navigation, the one problem of which is to find one's way from port to port. The need of a single land map without the exaggeration of this chart or the distortion of Mollweide's has now become as imperative as the need of a sea-map was in the sixteenth century.

In the new school of world maps, then, the problem is approached from a new viewpoint. And it may here be noted that many of the most brilliant discoveries and most useful inventions have been made by "outsiders" — men not trained wholly in that particular science to which they so often contribute so much.

It is not easy to indicate the first step taken to make land maps of the world as distinguished from sea maps; or when advantage was first taken of the contour of the continents by plotting the northern land mass on a plane tangent to the north pole, or at any rate parallel with the equator, with developed radial extensions. This type of world-map in which the continental peninsulas below the equator are carried in star-shaped extensions seems, however, to have originated in Germany, at least so I gather from a letter from Mr. E. A. Reeves, the map curator of the Royal Geographical Society of London. In *Germain's Traité des Projections* is an account of such a map brought out fifty years ago by Dr. Jager and modified by Dr. A. Petermann.

Another such stellar projection is described in Prof. Dr. Karl Zoppritz, "Leitfaden der Kartenentwurfslehre." Of this type, also, is the quincuncial projection devised by Prof. Charles Pierce, and another five-pointed star-map printed in Stieler's Atlas. In spite of the fact that some authorities contend that this type of projection is of little practical value, it is to be noted that it is being more and more used and that the geographies of the American Book Company make use of polar maps with star extensions in several of their publications. As this company is the largest school-book publishing house in the United States, and probably in the world, I consider this fact of very great importance. It is noteworthy that both a five-pointed and a six-pointed star-map are used by this firm. In the "Natural School Geography" (Redway and Hinman) a six-pointed polar projection, together with the hemispheres on the equator, are printed on a full page, as shown in Fig. 23. This star projection is printed in other parts of the book. The star extensions start at 20 degrees west of Greenwich on the equator, each being 60 degrees wide and having the bounding meridians curved. All parallels both north and south are concentric. On this map the northern hemisphere is plotted on a different projection from the southern, which occupies a larger area. The equatorial regions are very much distorted. Moreover, the boundary meridians of the southern star extensions are so poorly selected that parts of the East African coast are mutilated and sheared off along with Madagascar into a separate lobe, while a similar mutilation happens to the west coast of South America.

Another book, smaller in size, the "Eclectic Physical Geography," by Hinman, of the same firm, contains a five-pointed polar projection which is used four times for different purposes. In construction, the northern hemisphere down to the equator is similar to the six-pointed map, but the southern extensions are five in number and 72 degrees wide, commencing at the meridian of 100° west. This map is shown in Fig. 24. While Africa and South America are both shown intact, Madagascar is cut at longitude 44°, the dividing meridian, and most of the island separated from the lobe containing the mainland of Africa. On the other hand, New Zealand in this map is included in the same lobe with most of the Australian continent. But this is no advantage, because New Zealand is separated from Australia by over a thousand miles, and is, moreover, geologically, biologically and politically entirely distinct from the continent of Australia. But the island continent which should, in all logic, be wholly

included in a lobe of its own, has its entire west coast split off at the 116th meridian. Even Perth, the capital of Western Australia, is separated from most of the mainland. This dividing meridian, below the equator, also rends asunder part of the large island of Borneo and separates by a wide gap of space one half of the East Indian Archipelago from the other. Unlike the New Zealand group, these islands are part of one continental plateau, — geologically, biologically and politically one. No division could be more illogical and unscientific, and I have often wondered how such an impracticable and arbitrary projection could be described with so much mathematical pomp and circumstance as this quincuncial arrangement. It is also a matter of astonishment that so slovenly a map should achieve the dignity of being nicely engraved and colored and printed off in millions of copies. None the less with all its imperfections and mutilations, this projection is actually, for a great many purposes, far better than either Mollweide's or Mercator's. That is why it is used.

Still another polar map of the world, with eight-pointed extensions, is printed in an atlas published by J. W. Bartholomew & Co., of Edinburgh. The triangular extensions on this map contain 45 degrees of longitude each. The series commences at 100° East or 80° West. This projection is shown in Fig. 25. South America is slightly mutilated by the 80th meridian west, and so is Africa by the 10th meridian east. The Australian lobe cuts into Sumatra at 100° E. Longitude and at the 145th meridian east cuts the most important states of the Australian commonwealth in two, viz., Queensland, New South Wales and Victoria, to say nothing of the islands of New Guinea and Tasmania, which are also split asunder in this map.

It seems amazing that the originators of these star-shaped polar maps should seemingly have gone out of their way to mutilate the continents by dividing their maps below the equator into five, six and eight divisions, when the world itself is plainly, simply and grandly divided into four, viz., South America, Africa, Australia and Polynesia of the Pacific, dominated by the New Zealand group. Two of the systems just described began making the initial goring at longitude 20° West. Nothing could be easier than to include 90 degrees in each lobe from this starting point, and so develop a map of the greatest simplicity with all the gorings well out to sea. It is a truly astonishing thing, but it bears out the point I made at the beginning of my paper, that your mathematician often combines a prodigious amount of learning in his methods with a prodigious amount of

stupidity in his results. On the other hand, it must be admitted that simplicity in most things is attained by a circuitous route through all manner of complications.

All the maps described above have four serious drawbacks.

In recovering from one long-established error mankind is apt to rebound to an opposite extreme. Having long looked at the world from the equator in both Mercator's and Mollweide's projection, it is not to be wondered at that the first maps in revolt at this practice should go to the other extreme and view the world from the pole. This is the first mistake. The second mistake is that of crowding the whole northern hemisphere into one disk; and we have seen that no projection is wholly satisfactory which attempts this, because either the edges are too crowded, the center is too compressed, or the periphery too much extended. The third fault with the polar maps, above described, is the lack of symmetry north and south of the equator. That is to say, the method of projection for any one group of meridians forming a southern lobe, whether in five, six or eight sections, differs from the method used for the same longitudes in the northern hemisphere. Moreover, in the six-lobed map the extensions have curved sides like the petals of a flower. If the map is cut from the paper these southern "petals" when folded back will meet at a point at the south pole, but the sides will not fit, they will lap over one another. In the case of the five- and eight-pointed star-maps, whose rays are bounded by straight lines, when folded back the sections will, it is true, fit together, but the parallels of southern latitude will not be rings concentric with the south pole, but a series of five and eight concave loops looking somewhat like a spider's web; the result being that similar latitudes north and south of the equator do not correspond. Each is distorted in a different, a discordant, way.

The fourth error lies in the number of lobes or extensions on which the southern hemisphere is to be carried and the careless selection of the meridians delimiting the same.

The second and last error mentioned above have been avoided in a four-lobed polar projection invented by Lord Belhaven and published by J. G. Bartholomew & Co. (See Fig. 26.) While the mistake is made of putting the north pole in the most important place, and while the southern lobes are of a different type from the corresponding northern ones, this projection is an equal area one; the continents are correctly grouped, and advantage is taken of the shape of the land, which

makes it possible to include the northern lithosphere in a circular projection, which does not go lower than 25° N. Latitude. The splitting of the lower part of the map into four lobes commences, not at the equator, therefore, but at 25° N. Latitude, and 20° W. Longitude. A minor imperfection could so easily have been avoided that it is worth mentioning. As this map is printed, there is a mutilation or splitting asunder of Lower California on longitude 110° West and the peninsula of Gujerat on longitude 70° East. Now both these defects could have been so easily remedied by starting the articulated part of the map at longitude 25° West, just as it starts at latitude N. 25°. Why, in the name of sense and symmetry, this was not done before the map was so beautifully engraved, it is difficult to understand. With this readjustment of the split meridians the land masses remain intact. By goring 65° E. Longitude instead of 70°, the point of scission commences some twenty-five miles from the coast of Baluchistan and hundreds of miles west of Cutch and Gujerat. At the same time the goring at 115° W. Longitude and 25° N. Latitude is nearly two hundred miles away from the coast of Lower or Mexican California. By this change, too, the east coast of Australia is brought closer, but not too close to the map's boundary at 155° E. Longitude, about one hundred miles.

Thus amended, or even as it stands, this map is a great advance on all other polar maps with radial extensions. Nevertheless, as I have pointed out in my original memoir, published in the *Scottish Geographical Magazine*, this projection is in several ways unsatisfactory.

And here I should state the rather remarkable fact that, while I was preparing this account of my five years' work on this problem, Mr. J. W. Bartholomew sent me a progress proof of the Belhaven projection I have just been describing. I do not know how it is with you engineers, but we architects have a way of making plan after plan of a proposed building until we succeed in reaching the nearest to perfection that lies in us. And so with this map. I have made a great many sketch projections on all conceivable lines. Among these tentative experiments was one that was practically identical with the Belhaven projection, but amended as I have above described. The parallels drawn as concentric rings from the north pole down below the equator to the south pole, to secure equal area properties to the map, was suggested by the late Edward Wesson, Assyriologist and astronomer. This feature assumed pencil form, but was soon abandoned for a symmetrical arrangement of coördinates,

north and south of the equator, which was drawn in four straight lines at right angles to one another.

In explaining why this whole scheme was abandoned, I was criticising my own map at a certain stage, although I used actual features from the Belhaven map to drive home my argument and reasons for abandoning the polar aspect of my projection.

I quote from the original memoir:

"In projecting the circumpolar world down to 25° N. Latitude, it soon became evident that the attempt to crowd the spherical area of an inverted bowl on to a disk no bigger than the periphery of its rim was a feat involving grave error; to spread the bowl out involved error in an opposite direction. To include the bowl's actual surface on a circle somewhat between the two was a scientific solution but one involving serious distortion. Fig. 27 shows an 'elevation' and a developed 'plan' in 15 degrees gores of the world's top as described above. When the lower disk has been mathematically contracted, so that latitude is compressed and longitude is extended until the black wedges disappear, we have a circular projection such as is shown in the Belhaven map. But, in getting rid of exaggerations and attaining equal area properties, we have been compelled to distort the map as we recede from the pole, getting wider and wider in longitude and narrower and narrower in latitude until at 25° N., where the gorings commence, we have lateral distortion of Northern Africa and the whole region around the tropic of Cancer that is excessive. But, worse than this, having started on a career of ever-increasing distortion, so that degrees of longitude are very noticeably exaggerated at the rim of our northern disk, it is found necessary to keep on bulging our longitude (and also squeezing our latitude) right on for 25 degrees more until we reach the equator. The result is best shown by comparing Africa, Australia and South America, as plotted on this projection, with the actual shapes of these continents when viewed and mapped independently. [See Fig. 28 to 33.]

"While a great improvement on all other stellar projections, and while we have seen similar, though inferior, maps of this polar type put to considerable use for special purposes, it is clear that it is not good enough for universal use unless these defects of distortion and distance can be righted and other advantages added, especially in the matters of securing a uniform type of projection for regions north and south of the equator, and some means of adapting the same map to Austral as well as Boreal continuity.

"If, in addition to these good points, we can make our map roughly scalable in linear miles and so constructed that a large continuous world map can be made to fold into portable form for desk use, thus forming at once a regional atlas and a world map to a uniform scale, we shall, I think, have solved the problem originally set before us."

II.

A method of projection, like a plan or a recipe, is merely a means to an end. The proof is in the map, not in the mathematics behind it. No doubt the plans and specifications for the Quebec Bridge looked as satisfactory as those for the Forth Bridge. But the one collapsed and the other stands. No one can tell by examining the mechanism whether a flying machine will leave the earth or not. Yet a machine that will rise and one that won't look remarkably alike. I am impelled to these remarks by the comments made by some regarding the world map I am about to describe. I am told that my projection is "not dissimilar to other projections of the same kind, none of which have been found to be of much practical use." Now, I have described several in detail and have shown that some of them have been put to considerable practical use, in spite of their imperfections. It will also appear that the new map is not at all like other polar maps with radial extensions; the resemblance is a superficial one.

In all attempts to flatten out a spherical surface, one fact persists, and that is that there is always a region of maximum accuracy, and that this decreases as one recedes from this region. This region of maximum accuracy radiates from the point of contact in tangent circular projections and is transverse to the line of contact in cylindrical or conical ones. Now, the fault with Mercator's, Mollweide's and Van der Grinten's lies in the fact that all the accuracy is on the equator, which is not the most important part of the world. In the stellar maps, such as we have been discussing, all the accuracy has been centered at the north pole, which is very much less important. Is it not extremely illogical to waste the precious and restricted accuracy of a world map either on the torrid zone or the untraversed frozen Arctic? The perfect map will follow the good old Greek rule "to metron ariston," and, avoiding extremes of heat and cold, will center its interest and its accuracy at the temperate zones, between the two, where, not only most of the land of the world is grouped, but where the activities of the human race have reached their highest development.

In Fig. 18 the gores that make up a globe are arranged side by side at the equator. In Fig. 27 they are brought to a point at the pole. One sees at a glance that neither of these arrangements in the rough gives such coherence to the continental land masses as Fig. 36, which shows neither a cylinder around, nor a disk on top, but a cone athwart the world. You can see at a

glance that one only has to group the outlying southern ends of the world into four sheaths and the thing is done.

Fig. 37 shows the world drawn on this basis. A further improvement consists in goring the equator (Fig. 38 and 39). It will now be seen that if the boundary of the African lobe be shifted from 25° W. to $22\frac{1}{2}$° W., and the dividing meridian also carried $22\frac{1}{2}$° from the equator and the poles, that the whole map consists of eight equilateral curvilinear triangles assembled together on boundaries which for half their length are straightened.

In other words, each lobe has 90° of latitude and 90° of longitude. Half its boundary is straight and half curved. The temperate zones are in secant conical projection with straight radiating meridians. The parallels are concentric arcs of circles. In the Arctic and torrid zones the meridians are curved. Each lobe has shape and projection similar to each other lobe, and the southern lobes can fold under the northern lobes, so that the Austral hemisphere can be seen in the same relation as the Boreal hemisphere. Each lobe is based on an equilateral triangle (Fig. 40 and 41), and the whole world is contained in 240 degrees of arc, so that a repeat section can be added both east and west, as in Mercator's projection, to show how the beginning of the map is joined to the end. The map can be hung in seven different positions, each in turn giving maximum prominence to a different region, or it can be made to rotate. All the lobes can be doubled over each other, so that a folded atlas of pocket size can be displayed to the size of a convenient desk map of the world; or a regional atlas of folio dimensions for library use can be unfolded to the bold dimensions of a great wall map. All maps on this projection are to be printed to the same scale as the stock globes in use in the country of their publication. Tests with compass or calipers from the globe to the map will show that dimensions on the globe agree in the main with dimensions on the map, a test impossible to apply to any other projection known.

Although not a map for marine purposes, it will be found that as trade routes run east and west in the northern hemisphere and north and south in the southern hemisphere, practically all the important shipping lines of the world will show on the map in absolute integrity from port to port. And, since all straight lines on each lobe closely approximate arcs of great circles, the apparent route from port to port is also the real route. For an example, one has only to compare the course from Panama to Yokohama on Mercator's chart with the course on the new map, shown in Fig. 49 and 50 and elsewhere.

On Mercator's chart this course goes at least 1 500 miles west of San Francisco, if the ports are connected by a straight line. The real great circle route goes from Panama to Galveston, through Texas, west of San Francisco, out into the Pacific above Portland, up to Alaska and down the east coast of Asia to Japan. The course on the new map is practically identical with the course traced on a globe.

Regarding the property of correct "direction," the map shows lines of latitude and longitude crossing each other at equal angles throughout the entire temperate zones. These angles in the land regions of the torrid zone are also in the main equal to each other, the oblique angles of intersection being confined to the corners of each lobe.

A much clearer conception of this projection is made possible by realizing that only one eighth of the surface of the sphere is projected on to a plane, and that these eight maps are then assembled into one map as can be clearly grasped by glancing at Fig. 35.

When this drawing had been made and after the publication of the Memoir, I chanced to find in an old number of *Harper's Magazine* a map of the world attributed to Leonardo da Vinci. It is based on this idea of cutting the world into octants. No attempt, however, is made to fit them into one map, nor are they assembled together at their sides in the form of a loop or festoon by which the temperate regions are united, but they are arranged in a quatrefoil around a polar center (Fig. 34).

I will now show you a mechanical demonstration of the great accuracy of this projection. Long after it was developed and perfected, and after I had peeled oranges and laid the skins flat by the method of the map, it occurred to me one day to try the experiment on a rubber ball.

I took a hollow rubber one about 2 in. in diameter. On this I drew lines of latitude and longitude $22\frac{1}{2}$ degrees apart, starting at zero. I then carefully drew in the outlines of the continents. The result was a miniature globe on resilient rubber instead of stiff papier maché. Now, the principle of my projection, which, in a mechanical sense, consists in cutting the covering of a sphere so as to lay it out flat, can be applied practically to such a globe in a manner that demonstrates both the accuracy of the projection and the simplicity of its construction in a way that is absolutely and instantaneously convincing. (See Fig. 44 and 45 and compare with 42 and 43.)

Three great circles form the boundaries of the adhering

lobes, viz., (1) The equator; (2) $22\frac{1}{2}°$ West, including $157\frac{1}{2}°$ East; (3) also at right angles to this double meridian $67\frac{1}{2}°$ East, including $112\frac{1}{2}°$ West. These three great circles cross each other at right angles (and no more than three great circles can do so) at six intersecting nodes, two at the poles and four on the equator all well out to sea. Of these, two are at the east and west sides of the Pacific respectively, one is in the Atlantic and one in the Indian Ocean. Now, as we have realized that some sacrifice must be made to lay a sphere flat, and as we have agreed to sacrifice the oceans at the equator and the poles, we cut six Latin crosses in the covering of the sphere at these six nodes, each arm of each cross being $22\frac{1}{2}°$ long. And it is amazing to note how the very forms of the continents and oceans seem, as your secretary, Mr. Von Geldern, says, "as though made by design to fit this particular division and goring." No important part of the inhabited world is mutilated by these scissions. Now, when the four southern boundary meridians have been cut through, and one of the four northern ones, the rubber globelet can be laid out flat and put behind glass and photographed as in Fig. 44 and 45. When the glass is removed the rubber map leaps back of its own resilience and once more becomes a globe. The strain needed to flatten the rubber lobes has not even cracked the ink, and the minute change wrought on the surface by this flattening process is wholly imperceptible to the naked eye.

Now, if, as Professor See of the Mare Island Naval Observatory says, the ideal way to study the world is by use of a globe, and all geographers are agreed on this point, it follows that a map which is identical with the surface of a globe, laid out literally on a plane, must be the best as being nearest to an actual globe. Fig. 45 is practically a photograph facing eight sections of a globe laid flat. I will go further and say that a map so made has advantages that a globe has not. One of them is that the map shows the entire world at one *coup d'œil*, whereas on a large globe one can only see about a third of the earth's surface at one time.

Regarding these split rubber globes, one of which, I propose, shall accompany each school map on the new projection, Prof. Paul Goode of the Chicago University writes: "It seems to me that this device [the dissected globe] is the very best object lesson that has ever been proposed for connecting in the beginner's mind the relation between the map and the globe." He concludes by expressing the hope that these little toy globes should be in use in all the primary schools of the country.

Regarding the projection itself, I have received encouragement and endorsement from leading professors of geography and cartography in the universities of Europe and America, including Berlin, Paris, London, Oxford, Harvard, Chicago and California. Among cartographers I have received marked encouragement from Dr. M. Groll, of Berlin. Among scientists in general I treasure the approval of the venerable Dr. Alfred Russel Wallace, who expresses his appreciation of my projection as being " more accurate than any other yet attempted." An example of how this projection finds favor is quoted below from an article in the *Scottish Geographical Magazine* by Stephen Smith, B.Sc., F.R.S.G.S.

"*Every one who is interested in the teaching of geography should hail with satisfaction the production of a map of the world based on the method suggested by Mr. Cahill in his paper in the September number of this magazine. No projection of the hemispheres, stereographic or globular, no ' equal area ' projection of the whole of the earth's surface, no gnomonic and no cylindrical projection can give at once such a comprehensive and accurate representation of the globe on a flat surface as the map which is here shown* [*Fig. 42*]. *Its form is almost self-explanatory of the method of its construction, which is so simple that the merest child can easily understand it. Its accuracy is amply sufficient for all ordinary requirements. In short, it is admirable.*"

III.

Regarding the uses to which a new world map can be put, you will naturally have already come to some conclusions on this point when you have come to realize that so far world maps have in the main been made for mariners — " *ad usum navigantium* " is part of Mercator's title to his famous chart engraved in 1569. Theoretically, Mollweide's map is the one for landsmen's use, but its distortions are so repellant that a great publishing firm, J. G. Bartholomew & Co., of Edinburgh, instinctively reject it, and in their Commercial Atlas prefer the exaggerations of Mercator, in spite of the fact that the whole end and object of a Commercial Atlas is to show by patches of color the regions where various commodities are found, raised or exchanged for purposes of comparison one with another!

The selection of Mercator's projection by British map makers is probably due to the maritime training and habit of the British people, who have used Mercator's chart more than any other nation. But we have seen the evidence of dissatisfaction and various attempts to find a rational substitute. Unless, therefore, some map is adopted that commends itself to universal

adoption by reason of its demonstrably transcending merit, we shall go on using all kinds of world maps according to the taste and fancy of different publishers in different countries, and all this to the confusion of students and the hampering of science in general.

Now, a world map, by its very nature, should have an international quality. All nations have a similar interest in this, the ground plan of our common dwelling-place, the habitable earth. A broadly conceived simple symmetrical projection, therefore, which envisages the true shape of all the lands of the world without favor to any one region, an absolutely logical, truthful and impartial framework or diagram of the nations' boundaries by themselves and in their relations with one another, must inevitably prove a boon and a blessing to the whole civilized world. That such a suggestion should come from the New World about the same time that the scheme for a giant globe was projected in the Old World is not without significance. I say giant globe advisedly, for reasons which will appear later on. The official title of this great undertaking is, however, "The International Millionth Map." This project is a sort of splendid antithesis to the projection I have been describing, and you will note that etymologically the same word covers both extremes. The first proposed a huge analysis in map form containing all the geographical facts of the surface of the earth to a uniform scale, prepared by joint effort of all nations, whereas the second forms a compact synthesis to a small scale, whereby all the broad results of the great detail sheets can be focused and viewed in a uniform presentation for the benefit of all nations. The one is complementary to the other, as I shall show. Oddly enough, both enterprises were independently launched about the same time.

The idea of the great International Map of the World originated with Prof. Dr. Albrecht Penck, then of Vienna, now of Berlin, who, by the way, lectured at Berkeley four years ago. I was present at the lecture and made notes of it on the back of the manuscript of my map projection which I had just completed. At that time, however, I had never heard of Dr. Penck's proposal. It took definite shape later, at an International Conference called by the British Government and held at the Foreign Office in London under the chairmanship of Col. S. C. N. Grant, R. E. Mr. S. J. Kubel and Mr. Bailey Willis represented the United States. The British empire was represented by five delegates, including one from Canada and one

from Australia. Germany was represented by three delegates; France by four; Austria and Hungary by three; Russia, Italy and Spain by one each. No more momentous gathering ever assembled in the history of map making. It was proposed to map the entire surface of the sphere to a uniform scale of one millionth, in linear dimension, of natural size, which is one millimeter to the kilometer, or 15.78 miles to the inch. Uniform spelling and nomenclature were to be adopted. Elevations and depressions were to be shown by the hypsometric method of contour lines at designated altitudes; navigable rivers, roads, railroads, telegraphs, towns and boundaries, etc., were all to be shown by uniform prescribed symbols.

Now, regarding the most interesting feature of this map, from my point of view, viz., the projection, the reports in popular journals are confusing. Not only is the average man somewhat at sea on this question, but occasionally even experts make quite astonishing statements. For example, I opened a book the other day entitled, "The New Basis of Geography," by J. W. Redway, published by Macmillan & Co. On page 160 is the following: "The Mercator projection is intended primarily as a chart for the use of sailors. Its great merit lies in the fact that a straight line on the chart practically represents the arc of a great circle," the truth being that all lines directly north and south do, and one line east and west, the equator. All other lines, representing arcs of great circles, are curved, some very much so.

We are told that the giant map is to measure about 30 by 45 meters, or 100 by 150 ft., and that the projection adopted must allow every sheet to be fitted exactly with each of the other four sheets adjoining its four sides, and that the polyconic projection permits of this arrangement. This is a very misleading statement. One would imagine that each sheet, when added to its neighbor, would form a compact uniform map of the world on a plane 150 by 100 ft. If that were as easy as it sounds there would be no need to worry about projections. Of course, nothing of the kind is possible, as I shall show.

The explanation is of interest to engineers and architects, because it demonstrates that we are used to problems of projections in a more intimate and practical sense than either geographers or mathematicians, and also that the very last word in map making on the most colossal scale, and according to the most recently developed method, known as the polyconic,

is in effect a return to the simple methods of developing the coverings of solids, as taught in the rudiments of carpentry and building, such as are used to construct the forms for a dome or the paneling of a cupola. Each sheet of the International Map is to be 6 degrees wide and 4 degrees high. Starting from the equator there will be twenty-two rows of sixty sheets each, reaching to 88° North, where the series ends. They are lettered from *A* to *V* respectively. Each of the sixty sheets, between each pair of parallels, will be numbered from 180 degrees, which will be No. 1, to the last sheet, which will be No. 60.

Now, the polyconic projection is based on a central meridian, which is vertical. As each parallel is developed from a separate cone, the parallels are curves and the lateral or boundary meridians are necessarily curved also. If each meridian were added east and west to the central one, we should get a map based on the coördinates as shown in Fig. 22, a preposterous and ridiculous thing, and not at all the principle of the Millionth Map. On the other hand, if each sheet has curved sides, not one will fit its neighbor.

Now, as the curvature of the flanking meridians, on so large a scale, will be very slight, especially as each boundary meridian is removed only three degrees from the straight central one, I think I am right in assuming that the meridians on each sheet will all be straight lines. They will, however, be slightly inclined towards the center, which inclination will, of course, increase as they pass from the *A* belt at the equator to the *V* belt near the poles. Also, it is clear that all meridians on each sheet, if extended beyond, will meet in a common center. It is also clear that each sheet, with its entire series of lateral sheets, represents a small section of a series of truncated cones, 22 in number, the first one, *A*, being extremely pointed like the cap of a clown, and the last one, *V*, being extremely flat, like the hat of a Japanese 'rickshawman. Each successive apex, moreover, becomes the center from which are drawn the parallel concentric arcs of latitude.

The arcs of latitude are parallel or concentric to one another in each sheet only, because each sheet, as we go north and south, has a different center. Therefore the north and south boundary arcs do not exactly fit the boundary arcs above or below. But the difference in the width of one or two sheets is so slight that it may be ignored.

When the sheets are assembled in lateral rows, however, the parallels will meet at the sides of each sheet in a continuous

arc of a circle, each row of sheets, however, having its own special radius. (See Fig. 10 and 48.)

Now, this is not the polyconic projection as developed by Hassler for charting the eastern coast of the United States, wherein each individual parallel was developed on successive tangent cones. It is rather polyconic in the sense that each group of four parallels is developed on a separate secant cone cutting the sphere. That is to say, that a hemisphere is first conceived as a series of superimposed truncated sections of cones tangent to successive groups of parallels, each strip or ribbon of parallels, when unwound and laid flat, or developed, forming arcs of varying radius as we approach the poles. Each strip will contain sixty sheets.

Since there are sixty in number from east to west, and twenty-two from the equator to the poles, the total number for a hemisphere will be 1 320; add to this the polar cap, a polygon 4 degrees in diameter, and we get 1 321. Twice this will represent the whole sphere, which we now realize will contain 2 642 sheets. However, as each sheet narrows as it nears the pole, it was agreed that above 60° North or below 60° South two or more sheets could be united east and west.

Fig. 48 shows how a sphere by this method would be developed on to plane surfaces, which we see take the shape of arcs of varying radius.

This method of developing the covering of a hemisphere is taken from the chapter on "Stereography" in an old treatise on "Carpentry and Building." It is a useful diagram for working out the details of a dome, supposing that the vaulting were to be carried out on twenty-two equal courses of stone. In the illustration, of course, the number of strips representing the different developing cones differs from those on the map, but the principle is all the more clearly seen on few strips than on many.

It is evident from this diagram that the International Map was never conceived as a unit world map, but as a vast and uniform storehouse of geographical knowledge to be issued from time to time by or under different governments until the known regions were all reduced to the same uniform expression. As travel and exploration in less known regions progressed, the sheets would be reissued. Ocean charts, as well as land surveys, would, of course, be considered of equal, in some cases of greater, importance.

I need not emphasize the fact that this is a mighty under-

taking. It will be many years before all the sheets can be issued with even a fair amount of detail or accuracy, and, of course, it can never be finished and never be perfect.

Meantime, you will observe, by examining the diagram, Fig. 48, that any number of sheets can be grouped side by side in arcs whose radii vary with the latitude; or on top of one another in fusiform strips. Wherever these systems intersect, a cross or quincunx of five sheets can be perfectly fitted, but the four corners cannot be fitted in without leaving feather edge wedges of space, like joints between the original group and the added sheets in the corners.

We have now disposed of the continuous map idea, and shown that, like the world itself, the only way in which all the 2 642 sheets can be exactly combined is to paste them together (each row being at a slight angle to the row above), on a 42-ft. globe, or what is approximately a globe. Now, at the present moment, not more than five sheets have been published. By 1915 probably a few hundred will be ready, so that if a millionth globe were actually constructed,* and it would be a very expensive undertaking, only a few patches here and there would be ready to paste on it, the rest of the world would have to be filled in from our present knowledge.

Now, a glance at Fig. 48 will make it clear that it is possible to assemble the sheets of the International Map with fair compactness on a flat plane, if they are grouped in the triangular form, as shown on the central portion. If this grouping of 330 sheets is repeated for each octant, and each octant fitted to its neighbor, as shown in Figs. 35, 42, 43 and 45, we have, in a general way, assembled all the sheets of the International Map in visible display on one plane much as the marble tessera of a mosaic design might be laid in mortar to make the butterfly design there shown, the gaps and inequalities which we have seen to be unavoidable being taken up and absorbed in the jointing. In detail, however, the sheets would not fit each other exactly at the margins. If, however, each sheet of the millionth map were to be printed or photographed on some woven material, — linen, duck or silk, — so that each piece could be stretched a little vertically and shrunken a little laterally, and if some pieces could be warped a little diagonally, it would be possible to assemble all the actual sheets of the Great Millionth International Map, with all their details complete, on one comprehensive

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* See discussion, p. 207. — Ed.

cartoon. (See Fig. 46 and 47.) For convenience, such a map should be laid out on the ground and its mountains and hills done in relief in some suitable plastic medium. Color should be used only for one purpose: to show natural features, such as forests, cultivated land and deserts. Real water could be used for the oceans over variously tinted shades of green and blue, according to depths. Such a map would be about 136 ft. across. It could easily be constructed on the basement floor of some permanent building, the supporting columns of which could fit into the equatorial and polar gaps in the map. A railed and elevated gangway could be constructed to follow the sinuosities of the map in a continuous direction from start to finish. The underside of this gangway could be used to carry a line of electric lights and reflectors, so that the whole map under foot would be brilliantly illuminated, while the onlooker above moved in a sort of darkened limbo, unlit except for the reflected radiance of the illuminated "world" below.

In default of a permanent exhibit of this kind, a huge map on canvas to the full size of the International one would make a most interesting feature at the end of the great nave of the Educational Building of the forthcoming Panama-Pacific Exposition. If the map were marked off by latitude and longitude every four and six degrees respectively, a very graphic presentation would result of the exact size and number of the sheets of the Great International Map.

The particular projection which enables these sheets to be so united that the whole earth can be viewed in one plane would constitute San Francisco's contribution to this great enterprise formally inaugurated in London by the leading nations of the world.

Fig. 46 shows the coördinates of one lobe arranged in groups of one and two degrees, the patches hatched in show the exact relative sizes of the sheets forming the International Millionth Map. The groups of nine spaces show how nine sheets could be assembled at one time. See also Fig. 48.

Fig. 47 shows one of the finished sheets of the Millionth Map, The Boston Sheet, or "North K. 19."

I pass now to the consideration of the new projection of the world as applied to the science of meteorology.

Internationalism, now a sporadic and occasional thing, but destined in the future to be the keynote of all human endeavor, plays an important part in this science. The air above us knows no boundaries. A great storm depression a thousand

miles or more across, and traversing its own diameter in a day, starts in Siberia, crosses the Pacific, passes impartially over Canada and the United States and melts away in mid-Europe. No region of the earth under one government is large enough to track the whole path of any of those giant waves and depressions of atmosphere which are continuously traversing over the whole world.

Now, these " highs " and " lows," as they are called, are, in the main, circular. They are traced by connecting all telegraphic or radiographic reports of a uniform barometric pressure at a given hour. These readings are connected up by curved lines drawn on a map. From day to day they move, and the weather forecaster thereby can predict from certain observations the direction of these great waves and depressions, their velocity, the sharpness or pitch of their depression and the wind and weather developed in their track. This is done on a map. At present in this country Mercator's chart is used. See Fig. 49, which shows the North Pacific Ocean and United States as prepared by the Government, and another map including the same region and to the same scale, but drawn on the new projection, Fig. 50.

I have drawn on a globe three circles of exactly the same diameter, which I have transferred on to the latter map without noticeable change to their scale and shape. I have in the first Mercator map drawn these same circles by latitude and longitude. Now, it can readily be seen how a hypothetical storm movement changes its size and shape as it traverses different regions of the map, a fact that meteorologists find extremely baffling and inconvenient. On the other hand, a polar map gives undue prominence to the great frozen areas where no observatories are stationed and where no ships can send in radiograms. Moreover, the lower latitudes in such a map are unduly stretched and distorted.

Realizing these points, Prof. Alexander McAdie, the official forecaster at San Francisco, one of the most important stations in the Weather Service of the country, has written a paper entitled, " Charting Storms on the North Pacific," in which he points out that the new map has advantages over all others from the viewpoint of a practical meteorologist. The paper in question is now being published by the head office of the United States Weather Bureau at Washington, for distribution to all the substations throughout the country.

After quoting Dr. Cleveland Abbé as to the great import-

ance of a rational projection for maps, giving the general contours of storm areas, Professor McAdie continues:

"In charting storm areas it is apparent . . . that the Mercator distortion is so great that it may well be eliminated from further consideration. Nor can regional maps be used to advantage . . . because meteorologists now require reports from extended areas. Radio communication has made possible the girdling of the globe. And the necessity of long-range forecasts, leading in time to seasonal forecasts, is now pressing. For the successful accomplishment of this the atmosphere must be charted and studied as a whole. It is an interesting fact that the daily weather map now issued at Washington contains reports covering the area from Nome, Alaska, to Sedisfjord, Iceland; and there is every prospect that, in the coming years, the daily weather map, issued at various national central offices, will contain data for an entire hemisphere. It is particularly important, then, that some method of representing the earth's surface, suitable for the presentation of weather reports over the greatest possible area, and with the least possible distortion, be devised."

The writer then points out that the new map, as shown on Fig. 50, exactly meets the requirements. Professor McAdie has also shown, by actual experiment, that this form of map has mechanical advantages not found in other maps. One of these is rotatability; another is the advantage afforded by the extra two lobes. If these blank maps are printed on thin transparent paper, one can be imposed on another successively by means of one pin in the center. By placing charts of diurnal change over one another, the progress of "highs" and "lows" can be seen for several days, whence their ultimate direction can be easily predicted. A map on Mercator's projection, including Nome, the Philippines and Panama, can be supplanted by a map to the same scale on the new projection, which includes the entire northern hemisphere on a sheet that is practically the same size. In meteorology, it should be noted that north of the equator is the whole world to those who dwell in the north. The equator is a neutral zone south of which meteorological phenomena do not affect us as far as we know.

For South Africa, Australia and Argentina, of course, the same map can be used assembled around the South Pole, which has its own independent meteorology.

In view of the fact that there is talk of the organization of complete weather service in Indo-China and on the Chinese coast generally, including Korea and Japan, the need of more comprehensive surveys becomes obvious. While extensive

international coöperation is often a matter of difficulty and delay owing, for one thing, to the difference of language, etc., the observed area, as regards meteorology, could be very materially widened by a coöperation of the American and the British Imperial weather services, which would include radiograms from British shipping in transit. As this is 60 per cent. of all shipping on all seas, and as British outposts girdle the globe, a very good start would be made in one language. If France and Russia could be included in the agreement, and all these four nations are on the best of terms, the thing would be done. The reports in the French language would cover the whole of Northern Africa and the whole of Northern Asia not covered by Anglo-American ones. All that would be needed would be the establishment of meteorological stations at the right points over the vast areas of Russian Eurasia, English-speaking America and Franco-British North Africa, with suitable wireless apparatus, and the weather conditions of the whole northern hemisphere would be well in hand.

If other nations, such as Germany, took a hand, so much the better; I merely wish to point out that with the English and French language (the latter being the official language of Russia) the maximum world coöperation could be achieved with the minimum of red tape and diplomacy.

The southern hemisphere with transient shipping, the Falkland Islands, Polynesia, Australasia, South Africa and perhaps a spot or two on the fringe of Antarctica, is already in the British Imperial control, and if in such matters as quantitative rainfall in cycles, etc., it is ever made clear that the northern and southern hemispheres are interrelated, as possibly the statistics, when gathered, will prove, why, then the world at large is still further the gainer by an international enterprise of extraordinary importance.

From " China to Peru " mankind, in the main, is, above all things, interested in the weather. It is the first and last topic on one's tongue. The real wealth of the world is in what grows, and the main industry in this and all great nations is agriculture.

A good proof of the importance of maps, as used in the weather service of this country, is in the fact that the United States Government alone prints between seven and eight million weather maps annually. I regret to say these are printed on the wrong projection, but that is an error which can, and I hope will, be corrected in due time.

An important new use for maps of the world, and more especially maps without distortion or exaggeration, has been created by radiotelegraphy. No better map could be used, because every wireless station is the center of a huge circle, the possible field of its potentiality. A map of established stations throughout the world would show a series of giant rings each drawn with a different kind of line, and each intersecting some other ring. On such a graphic system, only possible on an accurate world map, can lines of world news be properly routed. Every radius of every circle must necessarily be on a common scale easily and quickly intelligible to operators all over the world, who also are accustomed to and educated to use a uniform standard type of map. For such uses the articulated folded map is of especial value, because of its portable form and the facility with which any outlying part of the map can be folded so as to line up with any adjacent sections.

It is a commonplace to speak of the shrinking of the world from the traveler's viewpoint. It is, moreover, no more expensive to go round the world than to stop at a first-class hotel. A map that would show world routes as intelligibly as a globe would be a boon to transportation companies and public alike. A folded world map, with all trunk lines of travel on land and sea in their true scale of distance and direction would be a revelation to that rapidly increasing class who travel over large distances for business as well as pleasure.

No better example of the special needs of an accurate world map, apart from the universal needs, can be brought forward than that of the colonial nations of the world and those nations whose territory covers immense areas like Russia, or whose territories are dispersed over immense areas like the United States.

The British empire covers nearly 12 000 000 square miles, one hundred times the area of the mother country. It extends over nearly all latitudes and all longitudes literally and not figuratively.

Indeed, I have established this amazing fact by careful examination of maps. Every parallel of latitude, from the southernmost point of the New Zealand islands to within five degrees of the north pole, passes somewhere through British territory with one exception of a few degrees which used to be British. Likewise every great circle of longitude from 0 degrees to 180 degrees passes through British territory, also with an exception of a few degrees passing through Kamchatka and

east of Australia. But, since 60 per cent. of ocean shipping in transit is under the British flag, the high seas are also, in a sense, more British than anything else.

Clearly, then, the British empire is in extent a veritable world empire and can be adequately mapped only on a world-map. That the need of such a map is keenly felt in the British Isles and in the Oversea Dominion is best realized by bearing in mind the agitation for Imperial school books, especially geographies, lately set in motion by such bodies as the "League of Empire," etc.

But the United States and France, Germany, Belgium, Holland, Portugal, even, have far-flung territories, colonies and outposts that cannot be shown at once on regional map, and which are utterly out of scale on Mercator's chart. For all these nations an accurate world-map makes a special appeal, and, while colonies and outposts of empire may be of little value in themselves, the mere fact of the possession or administration of them by a nation is a matter profoundly affecting the whole polity of that nation, for good or for bad as the case may be.

From the viewpoint of political economists, statesmen and students of *Welt Politik*, a proportional map of the world will furnish a graphic diagram of inestimable value. The same may be said of all naval and military establishments. The material resources, intercommunication and strategic configuration of the world's territories cannot be properly presented on Mercator's map.

The overwhelming preponderance of Russia in Eurasia, as displayed on Mercator's projection, has no doubt had some effect on the chancelleries of Europe and on the journalists who create public opinion and prejudice. By the same token, the resources and influence of China and India have been popularly minimized for the same reason. Not only do we of North America feel bigger than Africa but very much bigger than South America. Well, one asks, why not? On Mercator's map North America looks twice the size of South America. By measurement the continents have nearly the same land area, whereas Africa is more than a million square miles bigger than either.

The supporters of the "ABC" Alliance in South America will not fail to appreciate a world-map which does justice to the great mass of magnificent territory their alliance consolidates — an area of the world's surface a third as large again and as fertile as the United States and Territory of Alaska combined, and destined — who knows? — to as glorious a development!

You will have gathered the obvious advantages of a national map from the teacher's standpoint. The dissected globe makes plain the projection to a child, and the map's first use could easily be in the kindergarten. The ease with which one can master the world, as the Romans did, by dividing it, is a matter of particular interest. The eight equilateral divisions are so natural, and can be so readily explained by three knife cuts through an orange, that the way the continental outlines fall into each division can be easily and permanently fixed in the mind. Each vertical half of the world is divided into four parts, beginning at a quarter of a part west of o. Each side of each of the eight parts is again divided into four. By an odd sort of coincidence the spinal or central divisions seem also to divide or define the continents. The extreme of North Cape and the Cape of Good Hope are about on a central line. Cape Matapan, the southernmost point of Europe, is also on the same line. The high and low points of the Asiatic continent are both a little west of the center of the lobe containing them, and so is Cape Horn exactly in the center of the South American lobe. The same central line also passes through Cape Columbia, the northernmost point of the New World. The fourth set of lobes are water divisions, with the Hawaiian Islands exactly on the central meridian.

For scientific purposes of comparison of all world-wide phenomena whatever, for statistics, for graphic exposition after the manner now becoming more and more in vogue, no other map can have such a wide range of usefulness.

This subject alone, — perhaps the most important use of the map, — I could discuss at great length, but time does not permit.

I will conclude by calling your attention to a remarkable book published recently, which has been very favorably received throughout this country and Europe.

The book is entitled, "The Great Analysis: A Plea for a Rational World-Order." It is far ahead of the times; but as thought travels so much faster than action, this is to be expected. The unknown author starts out by assuming this world has now for the first time attained complete, or almost complete, geographical self-consciousness, and that it is about time for men, or the leaders of men, to begin to think, not "continentally," as Alexander Hamilton advised, but "planetarily." The author inquires "whether the time has not come when a World-Order may not be projected on the basis of a competent knowledge or forecast of all the factors. I suggest that a new

instrument of precision lies ready to hand, needing only an organizing genius, with a selected staff of assistants, to make effective use of it on a sufficiently comprehensive scale. . . . The instrument in question is none other than Statistics, in the widest sense of the term, the quantitative study of social and economic phenomena."

In other words, the author proposes a sort of joint action among all the leading nations of the whole world, with a view to systematic international coöperation in all matters whatsoever touching the welfare of humanity. It is a stupendous thought, not wholly new, because there was a sort of false dawn of the idea two centuries ago, but that the real dawn of such a movement is at hand, no thinking man will deny. Already it has begun. I have mentioned an international map and international meteorology. Recently we had the International Geographers amongst us. We know of several international languages from Volapuk to Esperanto. No science whatever but has now its international conferences. The postal, telegraphic, railway and steamship systems already have an international character; while banking, commerce, insurance and the flow of capital for industrial development are necessarily and inevitably international. Immigration and emigration, the solidarity of religion, labor, socialism and science are all wearing down the barriers of isolated nationalism. And just as the world is mathematically enmeshed in a vast reticulation of latitude and longitude, recognized by all civilized mankind, so it may be said that the material activities of the nations, too, are tied together in all directions with invisible filaments of mutual interest. A concerted movement to introduce order and purpose into the family of nations inhabiting the world is foreshadowed in the establishment of the Hague tribunal and in the movements for "international conciliation" and the abolition of war.

Now, as the author of the "Great Analysis" has said: "The human intellect, organizing order bringing, must enlarge itself so as to embrace in one great conspectus the problems not of a parish, or of a nation, but of the pendent globe."

Now, it was in an attempt to show the possibilities of instituting a part of just such a problem that gave birth to this world-map enterprise.

I sought to show the potentialities for permanent peace and world-order of the combined English-speaking nations as they now occupy the earth, and while my inquiries, too, were based on graphic statistics, which could only be possible on

the invention of a rational world-map, and while the inquiry would in the main be primarily economic, its ultimate implications might be accepted as universal and even spiritual.

Thus, as an instrument of geosophical analysis and a true portrait of Mother Earth for the use of all her children, I have hoped that this map projection will serve not only the humbler purposes of the statisticians, but the higher needs of the sociologist and the statesman, that even, as a means of quickening and clarifying international problems, it may come to serve the nobler end dreamed of by the poet, and help humanity a step nearer to that far-off ideal, — "The parliament of man, the federation of the world."

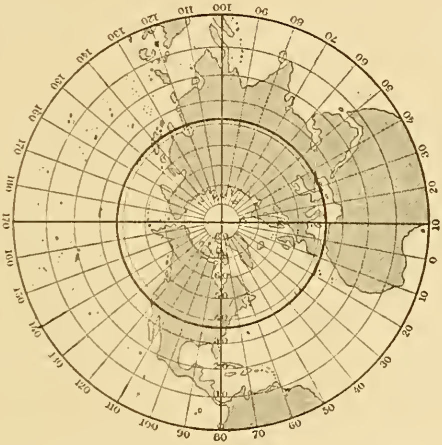


FIG. 1. STEREOGRAPHIC PROJECTION. On the plane of the equator.

FIG. 2. STEREOGRAPHIC PROJECTION. On the plane of a meridian.

NOTE. — In these and the following diagrams the actual size of the earth, as compared with the projection, is indicated by a circle in dark, heavy line. This will dispel the curious illusion that obtains in most of the twin disk and other circular maps, that the boundary of the map is a

sort of picture of the globe seen in perspective. The dark line circles in the following illustrations should all appear exactly the same size, for it is the intention of the author to assume the globe a constant uniform size throughout, with the projections consequently in their true relative proportion to the sphere they represent.

FIG. 3. GNOMONIC PROJECTION.
Plane tangent at the pole.

FIG. 4. GNOMONIC PROJECTION.
Plane tangent at the equator.

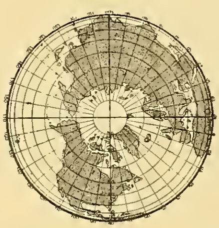


FIG. 5. ORTHOGRAPHIC PROJECTION.
On the plane of the equator.

FIG. 6. ORTHOGRAPHIC PROJECTION.
On the plane of a meridian.

FIG. 7. GLOBULAR OR LA HIRE'S PROJECTION.

NOTE. — For other examples of the Gnomonic Projection, see Fig. 9 and 15. Used in navigation for steamship routes and in astronomy for plotting meteor streams. The orthographic method is used universally by engineering, mechanical and architectural draftsmen. See Fig. 11. The globular is shown in part of Fig. 23, 24 and 25. See also Fig. 13.

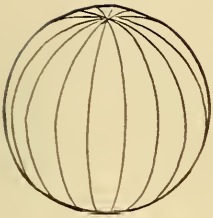


FIG. 8.
The World in Longitudinal Gores. Maps for globe makers. Radial maps. See Fig. 18, 27 and 36.

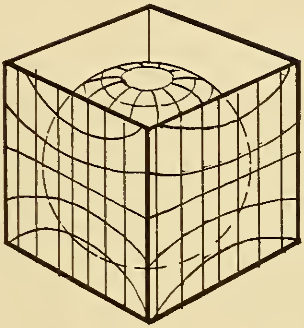


FIG. 9.
The World as a Cube, shown on Six Square Planes. See Fig. 3, 4 and 15.

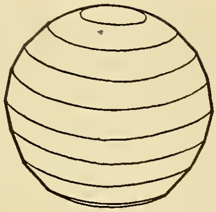


FIG. 10.
The World in Latitudinal Strips. The polyconic projection. See Fig. 22 and 48.

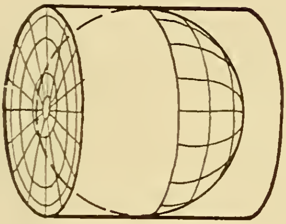


FIG. 11.

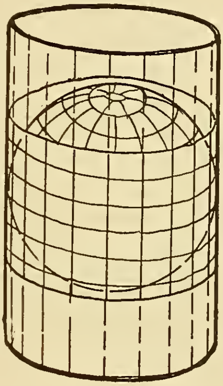


FIG. 12.

THE WORLD AS A CYLINDER.

The map of the world on the ends of a cylinder, the sides being left blank. Orthographic projection. See Fig. 5 and 6.

The world on the sides of a cylinder, the ends being left blank. Mercator's, Gall's, etc See Fig. 19.

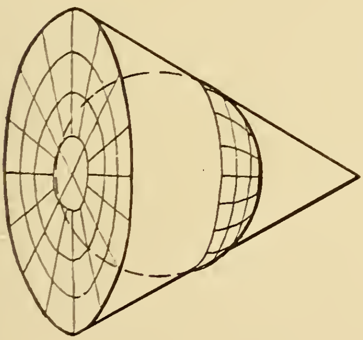


FIG. 13.

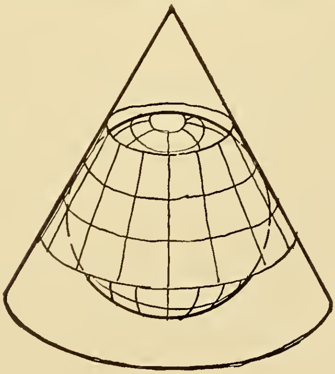


FIG. 14.

THE WORLD AS A CONE

The map of the world on the base of a cone, the sides being left blank. Stereographic and globular. See Fig. 1, 2, 7 and 23.

The map of the world on the side of a cone, the base being left blank. See Fig 40 and 41.

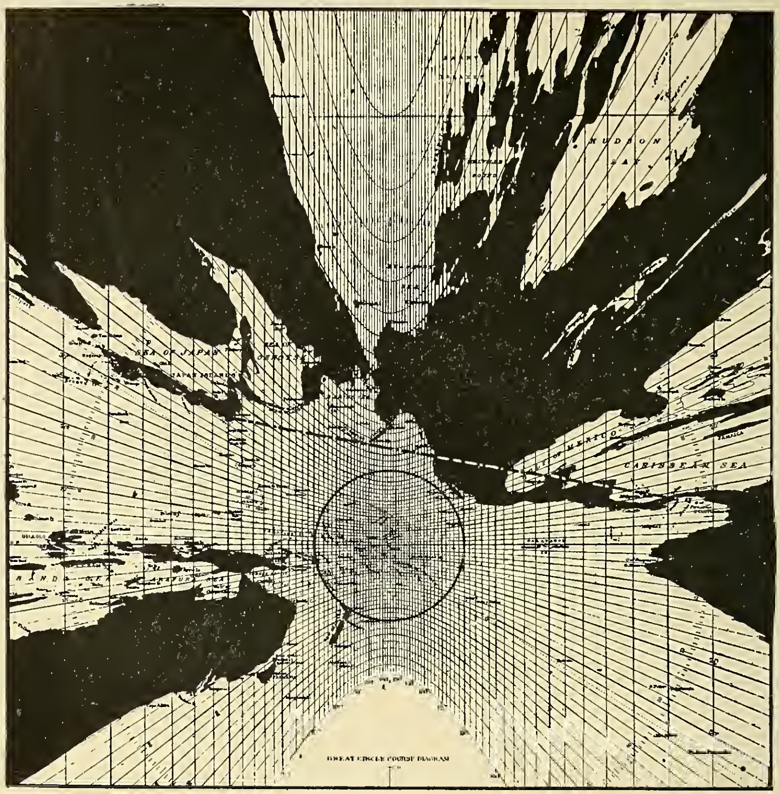


FIG. 15. THE PACIFIC OCEAN ON THE GNOMONIC PROJECTION

Showing that the better a chart is for mariners, the worse it may become for geographers.

NOTE. — This chart, called " Great Circle Course Diagram," is made at Washington at great expense, for the use of ship masters. Any straight line connecting one port with another across the Pacific will be an arc of a great circle, and, therefore, the most direct and economical route for a coal or oil burning vessel. This quality is not possessed by Mercator's chart. The heavy dotted line on this chart connecting Panama with Yokohama is the great circle short route. It goes through the Mexican Gulf, east of San Francisco, and skirts the Aleutian Islands. All the other world maps have this typical route indicated. On Mercator's, Mollweide's and Van der Grinten's maps this route errs by a thousand miles south (see Fig. 19, 20, 21 and 49), while in the polar maps the error is almost as much the other way, Figs. 23, 24, 25 and 26.

The new projection shows the course about right, Fig. 43 and 50, but without need of grotesque distortion whereby the edges of the map show the land masses going off into thousands and millions of miles towards infinity.

Fig. 16.

Fig. 17.

The British Isles Expanded to the Size of a Continent and Drawn to Mercator's Projection.

Note. — Both the silhouette maps of the British Isles are drawn to exactly the same scale. They are assumed to reach from the equator to 80° north latitude. The continent of Asia covers the same latitude and is as much caricatured and exaggerated on Mercator's chart as Great Britain is in the map above.

The North American continent is equally exaggerated on Mercator's projection, Canada, like Scotland, showing several times too big. But since rectilinear exaggeration is less easily detected and, therefore, less offensive to the eyes, Mercator's map has crept into general use where maps showing eccentric, oblique or curvilinear exaggeration or distortion are not tolerated. See Fig. 15, 20, 21, 22 and 49.

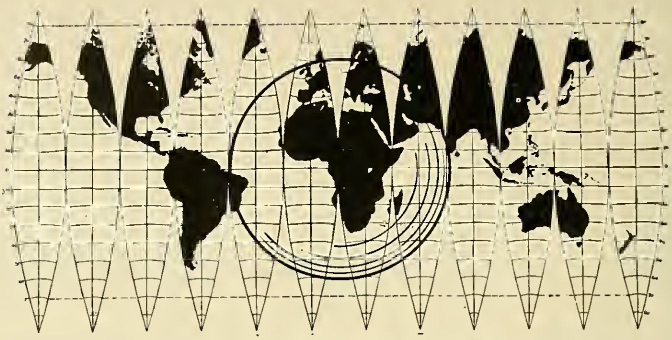


FIG. 18. THE GORES OF A GLOBE.

The paper gores of a globe peeled off and laid side by side. This map tells the truth about the globe as to the actual shape and size of the land masses. By carrying the sizes of Alaska, Greenland and Scandinavia in the mind's eye and comparing them with these areas in the maps below, one can compare the various projections with the normal facts. See also Fig. 8, 27 and 36.

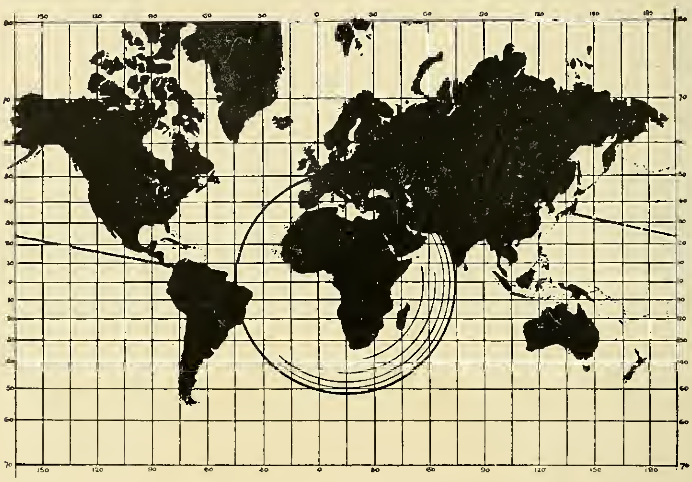


FIG. 19.

THE WORLD ON MERCATOR'S PROJECTION.

Note the enormous exaggeration of Alaska, Greenland, Norway, Sweden, Siberia, etc. See Fig. 49.

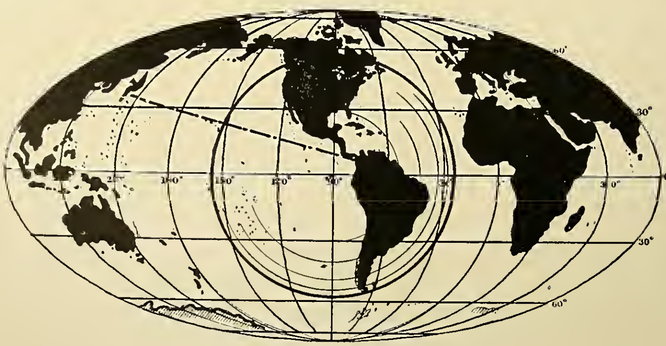


FIG. 20.

THE WORLD ON MOLLWEIDE'S PROJECTION.

All the above maps are drawn to the same scale. Both 19 and 20 are meant to represent the facts shown in Fig. 18. Neither the rectangle nor the ellipse can be made to cover the sphere.

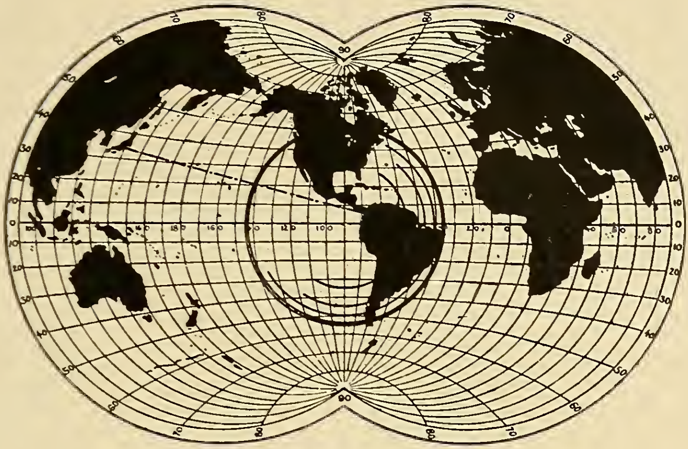


FIG. 21.

THE WORLD ON VAN DER GRINTEN'S PROJECTION.

NOTE. — This map is a compromise between the exaggeration of Mercator and the distortion of Mollweide's. But it does not remedy either defect sufficiently, while it sacrifices the advantages of equal angles and equivalent areas which make the first two scientifically valuable.
The above version of this projection is almost identical with one patented in England on July 13, 1889, by H. B. de Beaumont, of Geneva.

FIG. 22.

THE WHOLE WORLD ON THE POLYCONIC PROJECTION.

This projection for limited areas is the most accurate of all. For the whole world it is practically useless. See Fig. 10 and 48.

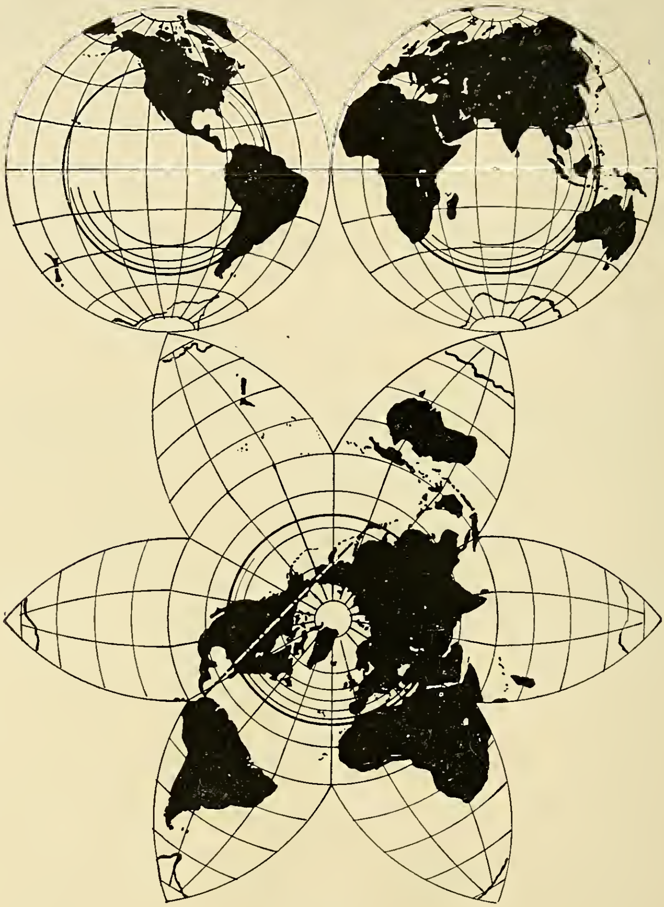


FIG. 23.

POLAR RADIAL MAP, SIX EXTENSIONS.

NOTE. This map is published by the American Book Company, and shows both the need of a new type of projection and the fact that there is a tendency to supply the need.

FIG. 24. A POLAR RADIAL MAP WITH FIVE EXTENSIONS.
Published in a physical geography by the American Book Company.

FIG. 25. A POLAR RADIAL MAP WITH EIGHT EXTENSIONS.
Published in J. G. Bartholomew & Co.'s "Handy Reference Atlas."

FIG. 26.

A POLAR STELLAR PROJECTION WITH FOUR EXTENSIONS.

Published by J. G. Bartholomew & Co. In this projection the gorings extend above the equator and the world is divided below the equator into four parts, a decided improvement on all preceding maps of this type to date.

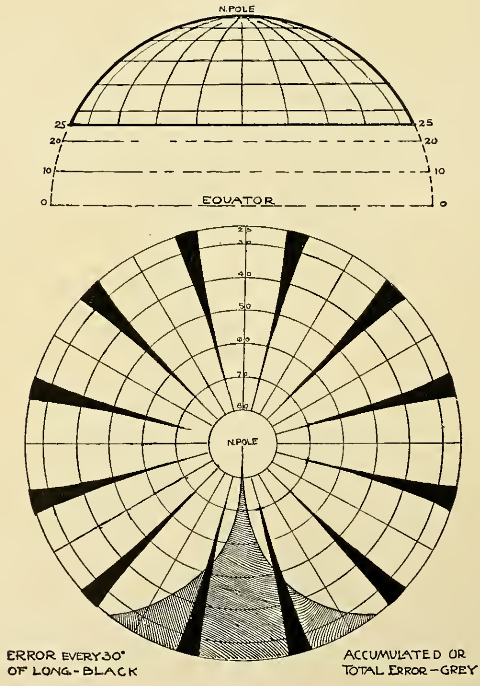


FIG. 27.

Showing necessary distortion of a polar map carried down to 25° north latitude, as in the projection shown in Fig. 26.

FIG. 28. AFRICA. FIG. 29.

FIG. 30. AUSTRALIA. FIG. 31.

FIG. 32. SOUTH AMERICA. FIG. 33.

NOTE. — Fig. 28, 30 and 32 show Africa, Australia and South America twisted and distorted as they come on the equal area polar map shown in Fig. 26.

Fig. 29, 31 and 33 show normal region maps of these continents to about the same scale. When drawn on the new projection these continents assume forms indistinguishable from Fig. 29, 31 and 33. See Figs. 37, 38, 42, 43, 44 and 45.

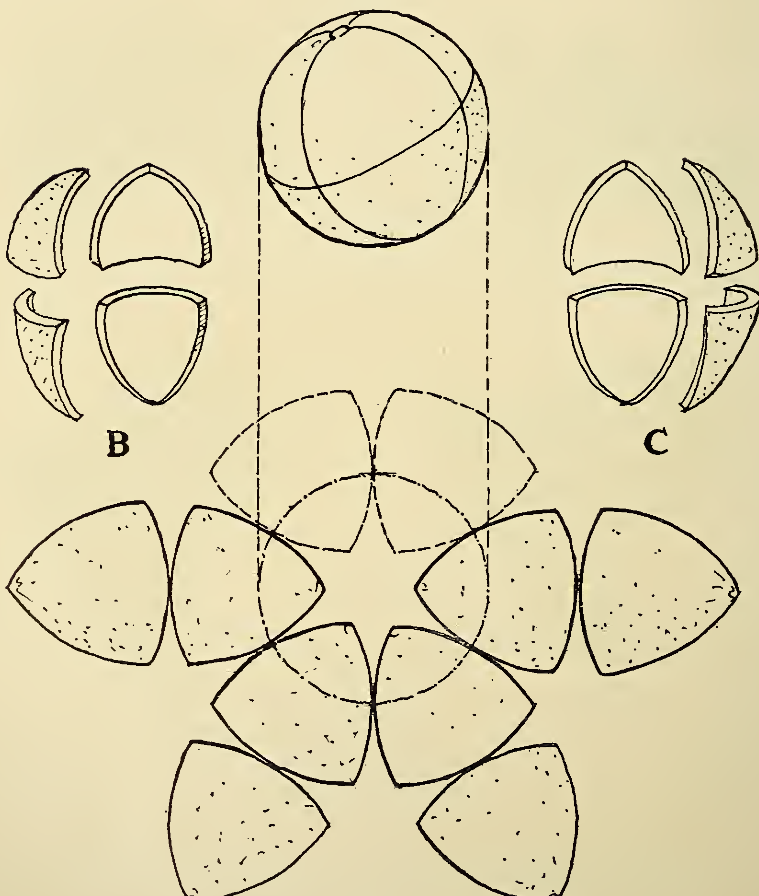
FIG. 34. LEONARDO DA VINCI'S MAPPE MONDE.

NOTE.—This interesting drawing was found by the author in an old number of Harper's *Magazine* (October, 1882) a year after he had made the sketch below, Fig. 35.

Da Vinci's map was found in Ms., and is dated 1513. The great artist and scientist here shows the southern hemisphere in four octants assembled around the south pole.

This map is said to be the first one on which the word "America" is found. It is interesting to see the south polar continent so well guessed at.

A



D

FIG. 35. EXPERIMENT WITH AN ORANGE.

Showing a method of assembling the world's surface in eight equilateral curvilinear triangles. When a half of each side is straightened, the eight sections can be united so as to carry the outlines of the earth without disruption of the habitable land masses. See Fig. 38, 42, 43 and 45.

FIG. 36.

THE GORES OF A GLOBE ASSEMBLED AT THE CENTER OF THE NORTH TEMPERATE ZONE WHERE THE LAND NATURALLY COHERES.

NOTE. — This scheme gives very much better results than grouping these gores centrally from the pole, as in all the radial maps heretofore described. If the southern ends of these gores be gathered into four groups, as in the next illustration, we shall have made the first definite steps towards a perfect world map.

Fig. 37 shows the world laid out from the viewpoint of the temperate zone, in preference to the equator or the pole, as in the maps heretofore described.

FIG. 38. ONE ARRANGEMENT OF THE NEW PROJECTION.

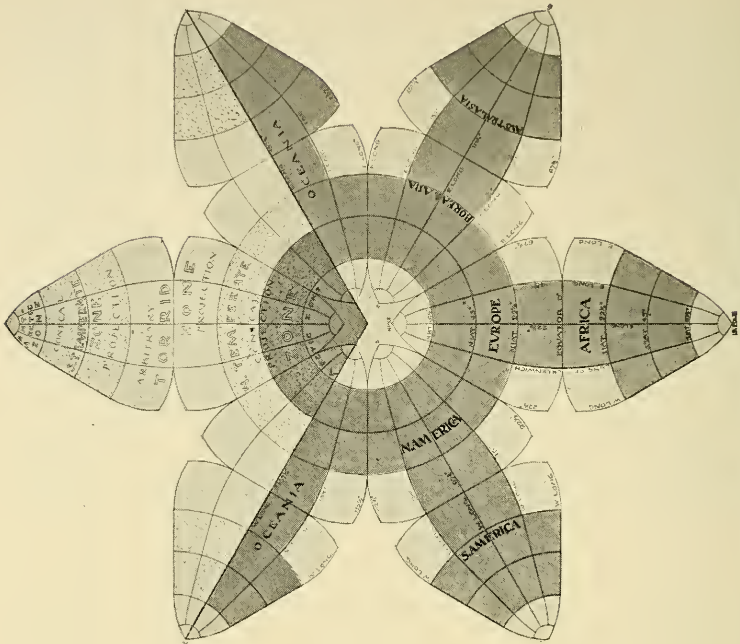


FIG. 39. AN ANALYSIS OF THE NEW PROJECTION.

NOTE. — The dark tone Fig. 38 shows the world complete, the light portion indicating the repeated lobes or half lobes. Fig. 39 shows how the different types of projection coincide with the zones of temperature and the angle of the earth's inclination.

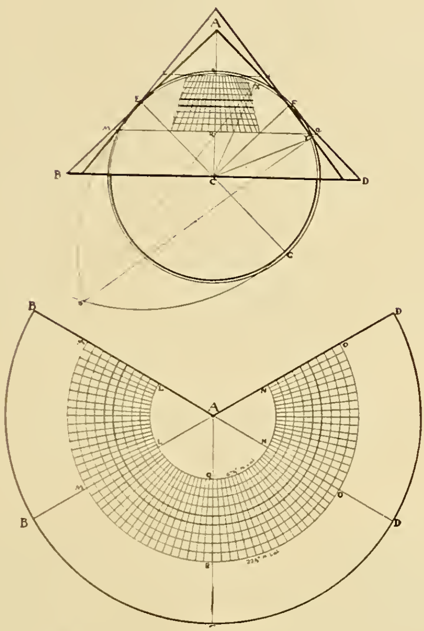


Fig. 40 and 41 show the geometrical principle of the new projection in which the north temperate zone is first laid out on a secant cone which is made to develop to an angle of 240 degrees. This makes for simplicity and uniformity of construction and permits the repeat of a full lobe at east and west of each map. Any octant of a sphere when projected squarely on to a plane becomes equilateral and equiangular. See Fig. 34, 35, 44 and 45.

FIG. 42. THE WORLD ON THE NEW PROJECTION.

NOTE. — In this map the Pacific Ocean is separated, while the Atlantic is shown complete. The clef or key which carries Kamchatka on the right upper lobe suggests pictorially that it is meant to fit the corresponding gap opposite Alaska.

FIG. 43. THE WORLD ON THE NEW PROJECTION.

NOTE. — In this map the Atlantic Ocean is separated, while the Pacific is shown complete. See Fig. 45, which shows mechanically the method of projection.

If the map be slewed around another sixth of a revolution, and the African lobes are thrown over to join the American ones, we have the world with America in the center and the Atlantic and Pacific on either side, an excellent arrangement for school use. In all these changes the actual map-sections remain the same. Only one drawing of all parts of the world is needed, the various arrangements being merely mechanical.

FIG. 44. EXPERIMENT WITH A RUBBER BALL.

NOTE. — The world is drawn on lines of latitude and longitude $22\frac{1}{2}$ degrees apart. When it is cut through in six crosses at the poles and on the equator, and these cuts are connected, the adhering lobes can be spread out into a plane and laid flat exactly like the map, Fig. 43.

FIG. 45. SHOWING BY MECHANICAL MEANS HOW THE NEW PROJECTION LITERALLY LAYS FLAT THE SURFACE OF THE SPHERE.

NOTE. — The rubber globe half displayed in Fig. 44 is here flattened behind glass. The strain is so slight that it does not crack the ink. When the glass is removed the butterfly map jumps back and reassumes the spherical form.

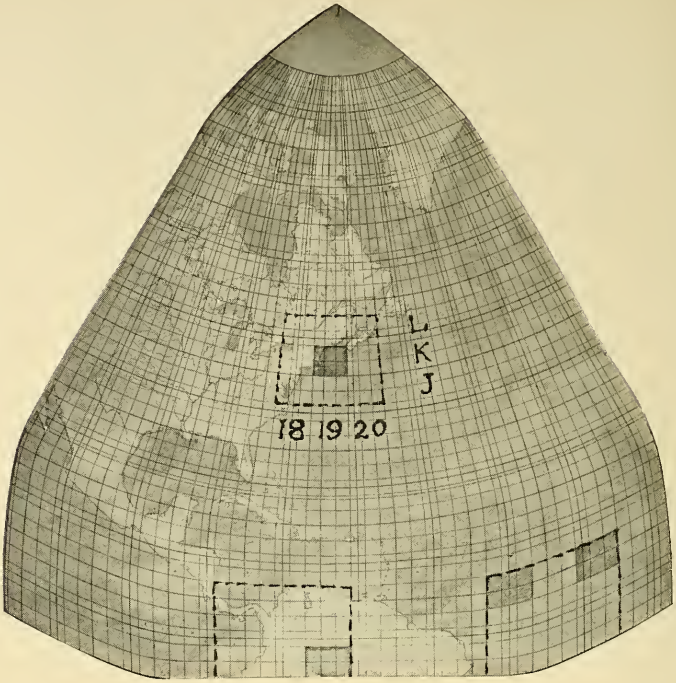


FIG. 46 and 47. (See next page.)

Fig. 46. One Octant of the New World Map.

Note. — This is reduced from a large drawing made originally to the scale of a 36-in. globe. The coördinates are drawn every two degrees and every fifth degree in between. The small shaded sections show the actual positions and relative sizes of the sheets of the International Millionth Map. The dotted spaces show groups of nine sheets as shown on the polyconic diagram, Fig. 48.

Fig. 47. Sheet "North K 19" of the International Millionth Map.

Note. — The only one published in the New World. Fig. 46 shows its actual position on the new map and the position of the eight other sheets that go around it.

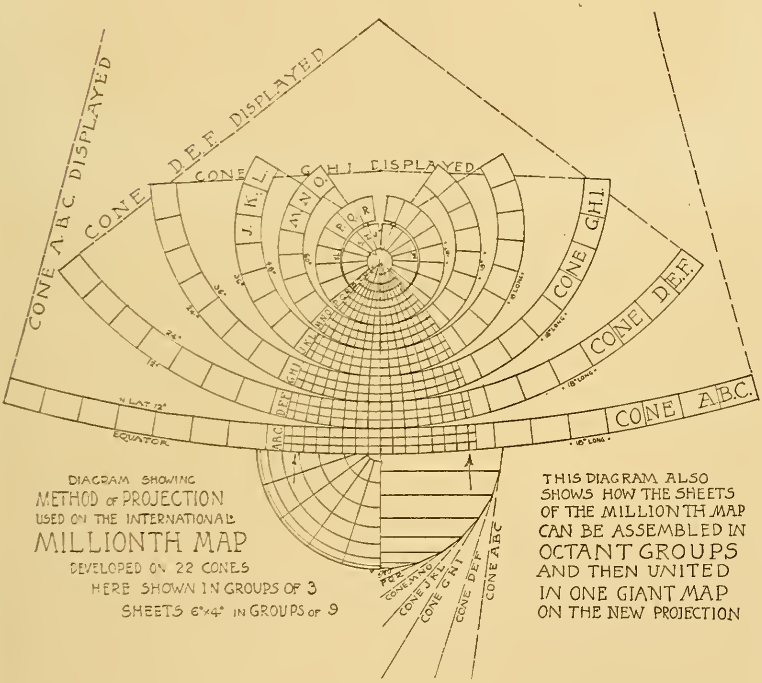


Fig. 48.

The Principles of the Modified Polyconic Projection as used in Constructing the Sheets of the International Millionth Map.

Note. — The Actual International Map is made on twenty-two cones for each hemisphere. For simplicity of presentation these are here shown three in one. It is assumed that nine sheets can be assembled without noticeable misfit in the jointing. If the central three-cornered group of sheets were mechanically packed closer by crowding the map at the lower corners, as indicated by the arrows, they would assume practically the form of the new projection, as shown in the octant, Fig. 46.

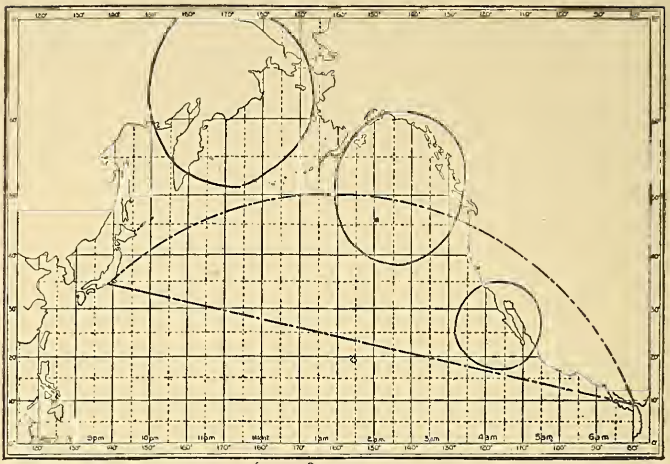


FIG. 49.

FIG. 50. THE NEW MAP IN METEOROLOGY.

The upper map shows three positions of a " low " on Mercator's projection. The lower map shows the same circles to the correct uniform size. On the new map exaggeration is avoided, and a far wider area of the earth shown on the same sized sheet.

Note also that on Mercator's map the *shortest* route from Panama to Yokohama is shown by the longer line.

On the new map the *shortest* line is also the *shortest* route.

DISCUSSION.

Mr. Otto von Geldern. — This is a most interesting projection of the world which Mr. Cahill has shown us and described to us to-night, and which he has developed after giving this subject very serious thought and study. The more I think of it, the better I like it.

Heretofore a globe has always appealed to me as the best geographical object lesson, but this, too, has its serious drawbacks; it is difficult to make measurements on a spherical surface, and only a portion of the world may be looked at at one time; in turning the globe we lose the relationship of its land locations.

I am convinced now that for showing the continents in their relative positions with a minumum of distortion there is no better graphic method available than Mr. Cahill's projection. A *land chart* comprising immense areas may be shown with greater relative accuracy by this method than by any other known to me.

It is well known that it is impossible to represent the surface of a sphere, or a large area of it, upon a plane without distortion. The usual methods for plotting land areas are applicable with sufficient accuracy for a comparatively small portion of the earth's surface, but, if the surface be a large one, the difficulty of retaining a unit scale becomes apparent at once, and increases with the size of the area to be developed.

There are a number of mathematical projections in use, each of which may well serve its intended purpose. Mr. Cahill has shown us a number of them. They are well known to geographers.

Mercator's projection, for instance, solved a great problem, and simplified navigation by an artifice deserving our fullest admiration. Yet its purpose is not to show the relative land areas, but to show relative bearings of land localities bordering the sea. Valuable as such a chart is for navigation, no one would recommend a Mercator projection for geographical land work. As we leave the equator and go towards either pole, the land representation becomes the most distorted deformity one can imagine.

The polyconic projection, which has its application in geodetic work almost exclusively, serves its purpose better than any other, and comparatively large areas may be represented by this method. The area of the United States, for instance,

is covered by 25 degrees of latitude and 60 degrees of longitude; in such a chart there is little distortion. At the central meridian, say, at Council Bluffs, the scale is true; but at the borders, say, at Boston on the east, and between Cape Blanco and Eureka on the west, the scale elongation is about seven per cent. The greater the area covered, the greater this marginal distortion becomes. It may readily be seen that the polyconic projection is not applicable to a representation of the surface of the world.

Mr. Cahill's projection overcomes the main difficulties, and lends itself primarily to land maps covering immense surfaces. It will show the areas of the world's continents, and their relative positions, with less deformation than any other projection. The author accomplishes this by adopting a segregation of the globe into uniform gorings of 90 degrees. This particular method was chosen after many empirical trials, and his result is such that it seems as though the continents of the world were made by design to fit that particular division and goring which Mr. Cahill finally adopted as the most suitable. It is doubtful whether a better scheme could have been worked out to give the same satisfactory solution, the underlying principle being not to sever the continents or to cut off any part of them from one flap to appear upon another, and to accomplish all this with the minimum amount of deformation of the scale. I think that Mr. Cahill has been successful in this.

While a globe will always lend itself as the best representation to the eye of the young and the untutored, land charts become necessary in connection with it, and to my mind now there is nothing that will give as clear and comprehensive an oversight of the situation as the projection which Mr. Cahill has shown to us to-night. It will appeal to any one after its main points have once been grasped.

Skeleton maps of this charcter may be used for innumerable purposes to illustrate commerce, wealth, population, industries, economic conditions, political, religious and racial divisions, weather and seismological statistics, and so on. The projection has an educational value because of its merits, the main one of which is simplicity.

Mr. Fred. Brooks (*by letter*).—Though Mr. Cahill's subject is the more widely important one of the map on a flat surface, he makes a reference to globes, consideration of which is a valuable addition to the discussion of maps, besides having much interest of its own. Mr. Cahill's passing reference may be supplemented by a few further observations. Though as Mr.

Cahill says (page 170), not all of the surface of a globe can be seen at once, a man who wished to see both sides at once might have two globes side by side, as he has two maps, one of each hemisphere, side by side in existing atlases; but as the human mind is not well adapted to attend to more than one thing at a time, this is an insignificant point. Half of the globe to be looked at at once may be chosen so as to include nearly all the land surface excepting Australia and the Antarctic continent; and it is that hemisphere of land which Mr. Cahill especially wishes to show rightly in the new map; so it is not in that point that the map has an advantage over the globe.

Mr. Cahill (on page 172) refers to a scheme for a giant globe as projected, and (on page 176) he speaks of the possibility of putting sectional sheets together on a 42-ft. globe, and uses the phrase "if a millionth globe were actually constructed." Why the "if"? Such a globe has actually been constructed. Being on a millionth scale, it had a circumference of 40 meters and a diameter of 12.73 meters, or about 42 ft. Topographical details were of course supplied independently of the newly formed international organization for gathering the material which Mr. Cahill mentions. It was "filled in from our present knowledge," to borrow his phrase (from page 176), but it was done under scientific auspices, and was done well for its purpose. The globe was a very interesting feature of the International Exposition at Paris in 1889. It was in a special building arranged with a spiral ramp so that visitors after having been taken to the top by an elevator could walk down going round and round the globe and seeing the different parts of its surface. It was turned slowly around on its axis. The framework of the building as well as of the globe itself was put together so that they could be taken apart and if desired could be readily set up again in some other place. There were 586 panels making up the surface of the globe; they were of pasteboard on a frame of wood.

For temporary exhibition purposes I think this globe, "La Terre au Millionième," superior to the very pleasing Millionth Relief Map, with real water, proposed by Mr. Cahill (on page 177) with reference to the 1915 Panama-Pacific International Exposition.

[NOTE. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 15, 1913, for publication in a subsequent number of the JOURNAL.]

ELEVATORS: THEIR USES AND ABUSES.

By B. C. Van Emon.

[Read before the Technical Society of the Pacific Coast, July 18, 1913.]

An elevator may be termed an ingenious mechanical device, invented and designed by man to overcome nature's imperative law, the law of "gravitation."

The overcoming of gravitation by the use of an elevator is by no means modern, for, many ages ago, history has shown that man had equipped a clumsy hand-power contrivance, whereby, with the use of considerable human energy, a greater weight was overcome by a lesser energy; but modern equipment, invention and devices place the elevator in a mechanical class entirely by itself. The towering buildings of modern construction, these massive structures of many stories, are rendered possible, practical and economically advantageous, only through the installation of the modern elevator, which, by its convenience in carrying passengers and freight to a higher or lower elevation and its accommodations for a practically unlimited number of passengers, increases property a hundredfold in its initial value.

Like most modern inventions, which many centuries ago were in crude construction, the completion and almost perfection of the elevator has been an achievement left for the present century. Thus, again, like the perfection of all other wonders which now seem to us so commonplace, the practical completion of the elevator has been a matter of slow evolution.

The combined mechanical genius of many elevator engineers has given to the public various types of elevator construction, of which a list is herewith presented:

Elevators may be divided into the following classes:

Handpower elevators,
Belt or power driven elevators,
Steam elevators,
Hydraulic elevators,
Pneumatic elevators,
Electric elevators,

each of these being divided into classes by governing conditions.

The *Handpower* Elevator is the oldest elevator known, patented in the year 1846. When used for handling freight in

buildings the machinery is generally located overhead and consists of a long wooden drum, with a large gear wheel attached to the end; this wheel engages with a smaller pinion driven by a large "bull" wheel, or wheel upon which a rope is placed, leading from the lower floor through the several floors of the building over this "bull" wheel; this rope is spliced and is made continuous. By pulling this rope the countershaft is made to revolve and drives the small pinion; this engages the large gear wheel which turns the drum upon which the rope is attached to the car, and in this manner lifts the freight. The sizes of these hand-power elevators, under this condition, vary, according to the work to be done, and are built for capacities of 4 000 pound or 5 000 pound loads at a very slow speed.

The next type of hand-power elevator commonly used is for sidewalk elevators, this type dating from 1858. The gearing or hoisting mechanism is generally built on an iron frame, and consists of gear wheels, ratchets and brakes. These frames are sometimes built of wood, with the gearing mounted as upon the iron frames, and are used for raising and lowering merchandise from basement to sidewalk level.

The *Double Belt Worm-Gear* Elevator, another type of elevator commonly used for handling freight, is driven with belts from the main line shaft in the building to pulleys on the worm shaft of the belt elevator. These are double belted, one belt traveling in one direction, the other, a cross belt, traveling in the opposite direction; and by the use of a pull rope placed conveniently in the well hole, by means of a mechanical device, these belts are shifted on and off the tight pulley on the worm shaft, giving the operator control of the direction of the elevator. When the rope is pulled to the neutral position, the belts are both off of the tight pulley and run on the loose ones. This same movement sets the brake on the tight pulleys and holds the car when fully loaded. The worm gear mechanism is enclosed in a cast-iron casing and filled with oil, and on the worm wheel shaft is placed a winding drum of sufficient size to accommodate the hoisting cables, these cables being carried up through the hatchway over a sheave on top of the elevator shaft, and down to the car. On the opposite side of the drum are ropes passing upward through the building over another set of sheaves, that are attached to a counterweight, balancing the car and part of the load, this arrangement giving the best results. These worm-gear machines were built in sizes as high as 6 000 pound loads and were considered very large elevators in the early elevator

days. However, even with the great advancement made in the elevator industry, a belt elevator is rarely built to exceed a capacity of 6 000 pounds even at the present day.

Later, the belt elevator was operated by an electric motor with a single belt running to the drive pulley, or tight pulley on the worm shaft. This electric motor was started and stopped by an electric switch which reversed the current in the motor, and gave it the direction required, thus eliminating one belt and giving a direct drive from the motor power to the elevator, and when the elevator was not in operation no power was being consumed. This was practically the next step in the elevator advancement.

Steam-Driven Elevators: About the period these belt-driven elevators were first used, there was also a steam-driven elevator, operated by steam direct to an engine, of the reversing type, somewhat like the "Brotherhood engine" used on steamboats to control the rudder. These steam-driven elevators were operated by a pull rope with a pilot valve on the engine almost in the same manner in which the steamboat operated its controlling mechanism with the rudders. The first of these engines were direct-geared to a drum, with suitable rope connections over sheaves overhead to the car and counterweights. Latterly, these steam engines were geared to worm geared machines.

The *Hydraulic* Elevator was developed about this time, and consists of a large cylinder with a piston and a piston rod running through a stuffing box properly packed, and on the end of the piston rod are fastened several wire ropes wound around a very small drum, securely fastened to a shaft, upon which is keyed a very large drum. This was what was termed, at that time, a "pull-back machine," and was run generally from the city water pressure or city hydrants. This was controlled by hydraulic valves for admitting water into the cylinder, and also discharging it into sewers. These elevators were quite commonly used about 1880 to 1890, at which time the electric elevator came into general use.

The *Plunger* or *Hydraulic Ram* Elevator. About 1882, the first plunger or hydraulic ram elevator, as it is termed, came into use. This plunger elevator consists of a piece of steel or iron pipe, which is turned true and smooth on the outside and operated through a stuffing box, which is securely fastened to the top of a piece of pipe of a larger diameter in which the smaller is enclosed. By admitting water on the top end of the larger pipe, in which the smaller pipe is placed, the water pressure will cause the

smaller pipe to pass through the stuffing box and propel the car in either direction when the control valve is opened, thus allowing the water to escape into the sewer. Plunger or ram elevators are set into the ground, a hole being bored of sufficient size and depth according to the travel and height of the building in which the elevator is to be operated.

At the present time, plunger elevators are built for almost any travel, up to 300 or 400 ft., and the water pressure applied is in ratio to the height of the building; in some instances, the water pressure required being 700 pounds per sq. in., varying, of course, according to the size of the ram and the conditions under which it operates. The writer will not enter into technicalities to the extent of figuring out accurately just what the strains are, and what the tension on the ram would be, under certain conditions, but it is a well-known fact that in tall buildings where the ram or plunger elevators are used, when the ram or plunger is a certain distance out of the stuffing box it comes under a pull instead of a push, and, in many cases, and almost universally in high buildings, it is necessary for the manufacturer to put a couple of wire ropes inside of the ram or plunger pipe the full distance, these being securely fastened at both ends very taut to hold the compression of the ram, so that when the stress or pull is put on the car after reaching a certain height it will not separate or pull apart at the joints, these joints being necessary in the plunger to keep it water-tight, and also assist in overcoming the strain which is placed on the pipe. This, it will be readily understood, becomes a strain or pull on the plunger after it has reached a certain distance from the ground or level at which the stuffing box is placed, caused by the increasing counterweight, this being necessary to overcome weight of the car and plunger, the same being generally made of steel pipe of a thickness sufficient to withstand the water pressure admitted in the larger pipe, around which the water is encased, which presses against the smaller or finished turned plunger which travels up and down the well hole. The plunger elevator is now being very successfully operated in tall buildings; the only drawback being the immense weight which constitutes the elevator equipment, also the time element necessary in starting, stopping and reversing this enormous weight in a given time. The stress upon the ram or plunger pipe, casing, control valves and other parts, is very great, as the water pressure is very high. An elevator equipment in a building of 300 ft. travel consists of the ram or plunger, the car with its counterweights, necessary to

properly balance the car, and plunger which must be very heavy; and it seems to the writer that the time element is very necessary in starting, stopping, and reversing this elevator; whereas an electric elevator made very light can be started, stopped and reversed much quicker, and, unquestionably, can run at any speed desired.

Admitting the plunger elevator for tall buildings to be very expensive, it being necessary to bore a hole in the ground equal to, if not a little more than, the total height of the travel of the car, it is a fact that the turning of the steel plunger or ram, the fitting together of the same, with the outside casing necessary to contain the high water pressure, the stuffing box at the top of the outside casing, with all its pumping apparatus and controlling apparatus, the necessary variable counterweights and all their accessories, must entail more expense than any direct electric elevator. Conceding that the starting and stopping of the Hydraulic elevator are much easier and more gradual, the actual running conditions of both are the same, and, so far as safety is concerned, the electric elevator is conceded by experts to be safer than the plunger type. In high buildings the electric elevator requires less for repairs, is less expensive to operate and costs less for installation.

The efficiency of the plunger elevator depends entirely upon its construction, and to make it efficient it is necessary to properly counterweight the same, so that as the plunger leaves the ground floor, and it comes out of its stuffing box, it pushes the car up; the counterweight in coming down must be so constructed that it will increase in weight equal to the same amount of the weight of the plunger coming out of the stuffing box. For example, suppose one foot of plunger should weigh 25 lb., every foot of counterweight that passes over the overhead sheave must weigh an equal amount, and it is readily understood that in tall buildings when the elevator reaches a certain point in its travel it becomes a pull upon the ram by the amount of counterweight that has passed over the sheave, and that the remaining part of the ram from this point in the shaft down to the stuffing box is holding back to this point over the counterweight, so that as the elevator ascends beyond this given point there becomes a strain upon the ram instead of a push. As before stated, to insure safety there must extend the whole length of the ram, and on the inside, a wire rope drawn very taut to make sure that the ram will not separate at one of the joints and allow the elevator car with its load to go crashing through the

roof, which actually occurred with fatal results in an Eastern city some years ago.

In the use of safety devices for the car it is necessary to have them so arranged that they will operate in either direction, because the safety devices must work in the reverse direction after the ram is placed under a strain by being out of the casing a certain required distance.

There is also another type of plunger elevator where the plunger is not placed in the ground, but is at one side of the well hole. This type is worked under somewhat the same conditions heretofore mentioned. In this type of plunger elevator, the weight of the plunger must equal the car plus the load. This plunger is held up by the pressure of the water, and when the load is lifted, the pressure of the water is released from the cylinder under this plunger, thus allowing the water to escape, and the excessive weight of the plunger over the weight of the car through its multiplication of ropes and sheaves will lift the car. When the car descends, it is necessary to produce a pressure in the cylinder great enough to lift this ram or plunger and allow the car to descend. Ordinarily, this type of elevator was a multiplication of " two to one " or " three to one " in the rope connections, and all of the work is accomplished through wire ropes connected to the car, over sheaves, placed overhead in the hatch. This type of elevator has the reverse features of the plunger elevator when the plunger elevator is a certain distance out of the ground, that is, the safety devices on this elevator operate in the opposite diection to those on an ordinary electric elevator, for if the cylinder which holds the water should break or a pipe should give way, allowing the water to discharge freely from the cylinder, the plunger would drop very rapidly, and the elevator would attain excessive speed in going up, and might result in an accident. These safety devices must operate in case the ropes should break, and prevent the car from falling, and they must be operative in both directions.

This type of elevator is very successfully operated at high speeds, can be started and stopped very quickly, and comes nearer the action of a direct electric elevator for high buildings than any other hydraulic elevator.

Another type of hydraulic elevator is the HORIZONTAL MULTIPLE-SHEAVE elevator. This type is generally placed in the basement of a building on the floor and consists of a large cylinder with a piston, a connecting rod and a set of multiple sheaves traveling on a cross-head mounted on a track. On the

other end of the cylinder is also placed a set of sheaves, equal to the number which travel with the piston and connecting rod, and as the water is admitted into the cylinder between the head and the plunger it moves the plunger out, thus pushing the plunger and sheaves upon the ropes passing around these sheaves, — the other end of these ropes being attached to the cylinder, — and thus lifts the car. In this type of elevator, the car is counterweighted to within a point wherein the weight of the car will overcome the water in the cylinder, and when the valve is open to lower the car the weight of the car must be sufficient to push the water out of the cylinder into the tank where it is again pumped under pressure. This latter is the most universal type of hydraulic elevator used for passenger service in high-class buildings, as the starting and stopping of this elevator is very gradual and accomplished without shock or jar, and it may be handled successfully at very high speeds.

Direct-Connected Electric Elevators. There are several types of direct-connected electric elevators, one consisting of the worm gear with drums attached and ropes fastened to the winding drums; another, the direct-connected worm-gear elevators with traction sheaves around which the rope is passed several times and run over an idler sheave, where one end of the rope is fastened to a counterweight, and the other end to the car. This worm-gear traction elevator is now coming into general use.

Another type of traction elevator is the "one to one" type, with the traction sheave securely fastened to the rotating shaft of the armature and the idler sheave directly over or underneath same, depending upon the position and condition under which the elevator is to operate. The ropes pass around these sheaves the same as in the worm-gear traction type of elevator. This type of elevator is capable of an unlimited speed, while the worm-gear traction drive elevator is somewhat limited in speed.

Again referring to the worm-gear elevators with their winding drums and ropes securely fastened thereto, it should be said that they are generally made in two types, one of a single worm and worm wheel, and the other, a double worm and two worm wheels.

The double-worm machine consists essentially of two worms in an oil-tight casing, one of which is made right hand, the other, left hand. The two worm wheels in which these worms engage are made right and left hand to fit, and they are so arranged that, in most cases, the two worm wheels constitute a

gear wheel, as well as a worm wheel, being meshed together, thus constituting a three-point connection between the right-hand worm and the left-hand worm and the two worm wheels which are gear wheels, thus giving the double-worm elevator its superior working qualities and strength over the single worm, because it has double the amount of contact or wearing surface between the worm and the wheel, thus allowing the use of a much larger motor and doing much heavier duty than can be done with a single worm, since there is a limit to the amount of work that a worm will do under a given load and speed. This double-worm elevator, or tandem worm-gear elevator (as it is commonly known), is only used for high-duty purposes, that is, where it is high speed with ordinary heavy loads for passenger service.

In some instances these worms are cut a double pitch, there being two worms of the right hand and two worms of the left hand, thus giving what is termed four points of contact for driving the worm wheel upon which is fastened the winding drum, around which the cables are wound. These worms are always made of a very high grade of steel, and the worm wheel also is made of the best grade of phosphor bronze, thus giving the best metals known for heavy friction at high speeds. These worms are operated, in some cases up as high as 1 400 rev. per min. and are giving excellent service at that speed. They are all enclosed in an oil bath with a special oil for the purpose, and when doing very heavy duty become quite warm at times.

With all of the worm-gear elevators it is generally conceded that, if properly constructed, the efficiency is about 50 per cent., and in instances less than that; so that in placing the electric motor for an elevator of a given duty, it is necessary to put on a motor having a capacity not less than 50 per cent. greater than the theoretical work to be performed, and in many cases as much as 75 per cent. greater capacity. It is also necessary to have a motor which will do at least 50 per cent. excess duty for a few moments in starting the load and getting under headway in a given time. It is now the rule for manufacturers of motors for elevator purposes, to build them for what is termed "intermittent duty," so that they will stand an excessive overload for a few moments and also operate at their normal horse-power and carry the load for the time required. These motors are now built especially for this purpose with large extra shafts, extra strong windings, and other features necessary to meet the severe conditions under which an elevator motor is to operate.

Controlling devices for these motors are also built by manufacturers who make a specialty of that class of work, and who have made an exhaustive study of the duties required for controlling apparatus. The advance made in the last few years in such apparatus is very marked, as the elevator controllers at the present time are much more durable than in former years, are simpler, more efficient, less liable to breakage and are somewhat cheaper, owing to the large number now being built.

There has also been developed within the past few years the full magnet control for alternating-current elevators. These controllers are built in all sizes.

The difficulty in the past has been that the laminations for the working parts of the solenoids or the magnets required to operate the switches have made too much noise, and in operation would heat, and the constant expansion and contraction of the laminated parts loosened them and broke them down completely. But these A–C solenoids and magnets are now so constructed that they do not heat and the noise is at a minimum, thus giving excellent service in operating the switches. No doubt in time there will be a marked improvement in the A–C controlling mechanism for elevators. They are also well developed for the full automatic control elevators such as are used in apartment houses, and their cost is but very little more than for the D–C apparatus to do the same duty.

During the past few years the A–C motor for freight purposes has made marked progress and is giving good service without interruption.

Within the last year or so an A–C motor has been introduced for elevator purposes which can be thrown directly across the line using a reversible switch. These motors are very simple. They have an enormous starting torque, from two to three times their normal running torque with about the same overload of current necessary to produce this torque. This makes the A–C motor very valuable for small freight elevators. These motors are now built so that they run very quietly and are very flexible in starting.

In the larger motors, for heavy freight duty and also for passenger service, what is termed the "slip ring armature resistance type motor" is used, operating with practically the same device that operates a direct-current motor, and the resistance in the armature is cut out in several steps by a control magnet, operating cut-out contacts, for cutting out or short-circuiting the armature resistance as the motor comes up to

speed, thus giving it from two to three times its starting torque and holding the same until the armature resistance is completely cut out. This development in the A–C motor has been very beneficial to the elevator manufacturer, since prevailing current supply is now alternating, and it is only a question of time when the direct current will become obsolete.

The first electric motors for power came into use in 1886 and 1887. These electric motors were operated from the old constant-current arc-light machines, viz., 9.6 amperes of constant current where the voltage varied according to the load placed upon the electric motor. These motors were controlled by shifting the brushes on the commutator, and were, at that time, the only known electric power which gave commercial satisfaction. A great many of these motors were built in San Francisco from 1886 to 1890. The old constant-current motors were built up to 15 h.p. and as high as 20 h.p., this latter being considered a large motor. They were belted to countershafts for driving pumps for pumping water into a tank on the roof, or in a steel compression tank under air pressure, where the water under pressure was used to operate the elevator, it being discharged from the elevator into a surge tank and then repumped under the pressure required to operate the elevator.

About 1890 appeared the constant potential motor which is now in use, that is where the voltage is kept constant and the amperes vary according to the work to be done, and wherein the motor does not require a governor to operate the brushes to control the speed, but where the brushes of the motor are fixed, the speed depending upon the adjustable relations. These motors were much cheaper than the old constant-current motor and gave better results. About this time all of the controlling devices necessary to start and stop the electric motor which operated the pump were also perfected. Some of the apparatus is in use at the present time, giving fairly good service.

In 1891, the writer patented a direct connected electric elevator. This was a tandem-geared, or double-worm machine with a right- and left-hand worm and a right- and left-hand worm wheel. This worm wheel consisted of two gear wheels spirally cut on about the angle and pitch of the worm, and the worm wheel was hobbed out of the center sufficiently to make a proper contact between the worm and the worm wheel. These worm wheels were made of common cast iron accurately machined, and the right- and left-hand worms were made of phosphor bronze securely keyed to the worm shaft. Upon the end

of the worm shaft an electric motor was installed, designed and built by the writer. Also all of the controlling mechanism was operated mechanically by reversing switches with springs, lever and dash pot which cut out the armature resistance as the motor came up to speed. This elevator was sold to the Keil estate and placed in their building at 770 Mission Street, occupied by Hulse-Bradford Company. The elevator did good service up to the time of the great fire of 1906.

About this time the writer patented a larger elevator of this same type, the motor and control however being of a different type from the above This elevator was placed in the Old Cliff House about 1892 and did good service until it was destroyed by fire. This installation was first operated from 110-volt circuit of direct current, and was later changed or rewound for a 220-volt circuit. When the electric railway was built to the Cliff House, it was again changed to 500 volts.

The single-worm elevator was then developed by the writer, who later patented several devices for controlling elevators, and after much study and experience these devices were brought up to satisfactory efficiency.

Since 1900 the development in electrically controlled elevators has been very marked, and the writer predicts that the advancement in the next thirteen years will be equally as great.

About 1898 or 1900, the eastern manufacturers realized the importance of the demand for electric motors and electric controllers for elevator purposes, and they made a study in detail of elevator equipment, viz., the making of motors especially for this purpose, also a controlling apparatus made for controlling freight and passenger elevators electrically driven. The constant usage of these motors and controllers has exposed their weaker points, and they have now reached a point of efficiency where they are commercially a great success, also being economical and practical in their operation.

Within the last few years, in the electric motor especially, there has developed what we term the "interpole motor," which has eliminated the commutator trouble originally had with reversible motors under heavy duty with varying loads.

The writer wishes to state a few facts regarding the care, maintenance and abuses of elevators. We are aware of the many advantages to be gained by good elevator service in buildings equipped with the modern elevators of the present day.

Good Service. It is not enough that the owners get from the manufacturers a first-class machine; they must do their part,

employing good, reliable, intelligent men, who are capable of understanding the importance of keeping all parts well cleaned and properly oiled, and who understand making adjustments when required, thus in many instances lessening the liability of accidents and reducing the up-keep of the machinery very materially; and the writer would ask the consideration of owners and the public for the elevator manufacturer, who is the man who is blamed for all the mishaps, accidents and unsatisfactory results, while as a matter of fact these conditions in many instances are caused by lack of care and attention on the part of the owner or, more often, the tenant. Then again, many troubles can be traced to the architects or engineers, who, when planning the buildings, fail to make the proper allowance of space for elevators; also, conditions are many times disadvantageous, such as poor light, etc.; and many other conditions obtain, all detrimental to a successful installation of what is conceded to be a most complicated mechanical contrivance.

In many instances, the owners of buildings consider their responsibility ended with the payment of the manufacturer's bill, forgetting that only by eternal vigilance and care can any machinery give good service; elevators are certainly no exception to this rule.

An elevator doing heavy duty in a building is a very essential part of the building, and when the elevator is out of commission the expenses of the building are just as great, without any results. Owners should realize that elevators should be taken care of by men experienced in elevator mechanism.

The writer will give the following illustration to make his meaning plain. Not long ago he was called to a rooming house to figure on putting in a new commutator on a motor which had been running for several years. The motor and controlling devices were placed under a stairway leading from a back entrance into a basement; part of the elevator machinery being in one room, a partition under the stairway brought part of it in another room. The controlling devices were so close to the wall as to render it absolutely impossible to reach one side at all. In this room were four old barrels full of inflammable matter, one of which was placed directly against part of the controller. It would have been easy for a spark from the controller to have dropped into this barrel. Undoubtedly this would have set fire to it, thus endangering the whole building. Around the machinery, the oil was ½ in. thick. Old rags, boards and shavings covered the floor. This elevator was in the care of a Japanese,

who could neither speak nor understand English, consequently it was impossible to make him comprehend that the elevator must be kept clean. Doubtless these conditions exist in many other cases in this city.

The writer suggests that, when owners and architects of buildings decide upon the elevator equipment required to meet the conditions under which the building is being built, it would facilitate matters to employ an elevator expert, who as an expert should be qualified to give them information valuable to insure good results, inasmuch as it is very material that the elevator manufacturer should understand the details, viz., how many entrances there are to the car, how the overhead supports should be constructed, what room and provisions are to be made for the semi-automatic gates, whether or not a freight elevator is required, and also the conditions required for fire hoods and fire doors, and much other necessary information. All of this is required to make a successful installation, and conduces to the owner's benefit, insures satisfactory results to the lessee of the building, and last, but not least, is of great assistance to the elevator manufacturer in helping him to thoroughly understand just what is required.

You will understand that the elevator contractor, in bidding upon the installation of an elevator, in most instances only receives a few of the actual conditions under which the elevator must give service, such as the load, speed, travel and size of car, etc. This is only a part of the information he should have. In order to bid intelligently, he should know every gate, fire door, and many other conditions with which he should be thoroughly in touch in order to insure a good installation.

The writer knows of several instances where the architect has designed a concrete well-hole, or a brick well-hole, without any recesses on the inside for gates; these shafts, being constructed for fireproof purposes, must necessarily have a roller drop fire door on the outside, this door completely covering the entrance. The gates must be put outside in the room beyond this roller door and the contractor is obliged to drill through the walls to put connections through, so as automatically to trip the gate when the car leaves the floor. Gates installed this way are invariably unsatisfactory. The writer suggests that when architects or engineers require bids for elevators it would be advisable to have a complete drawing made of gates, doors, automatic locks, safety devices and other things necessary, so that it may be determined how they should go into the elevator installation,

these drawings accompanying the specifications of the material to be used. Then the bidder has full knowledge of what is required and is able to bid intelligently, while without this knowledge the elevator contractor is compelled to use his own judgment, and in many instances it is at variance with the ideas of the architect and owner and often leads to confusion and dissatisfaction to all parties concerned. Hence, the writer's reason for suggesting the services of a competent elevator engineer to make the lay-outs and specifications for the bidder.

In Conclusion: A good, efficient elevator installation is of vital importance to all concerned in the elevator equipment of a building, and in order to obtain this the architect and contractor must work together to this end and for their mutual advantage, the architect giving the contractor all necessary data, etc., and the contractor, upon the other hand, assisting the architect by giving him the benefit of the knowledge of actual experience.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 15, 1913, for publication in a subsequent number of the JOURNAL.]

THE MANUFACTURE AND USES OF PORTLAND CEMENT.

By L. M. Bailey, Member Utah Society of Engineers.

[Read before the Society, May 16, 1913.]

It is a far cry from the experiments of John Smeaton in 1756 upon the nature and uses of hydraulic mortars and the consequent building of permanent foundations for the Eddystone Lighthouse, down to the practice of a modern cement plant and the building of the Panama Canal locks; and a very large number of things have happened along the road. Those of you who are sufficiently abandoned to admit an acquaintance with the writings of Walt Whitman will be warned when I tell you that the bare list of the steps in this development reads like one of Whitman's endless recitals of the things he saw and thought about. I shall not try to give you more than a rough outline of the subject with the hope that you will find it sufficiently intelligible and suggestive to form a basis for the discussion of such special features and details as you may be interested in.

Portland Cement, as we know it, is an artificial and practically a unique product; but it has a few more or less distant relatives, and a brief sketch of its family tree may help to make clear its position among the other mortar or binding materials.

Mortars may be classified as follows:

1. Common Limes: Made from comparatively pure limestones; burned at low temperature; slake with water; are non-hydraulic.

2. Hydraulic Limes: Made from impure (clay) limestones; burned at low temperatures; slake in water; show hydraulic properties — that is, will harden under water.

3. Puzzolan Cement: Mechanical mixture of volcanic ash, tufa, furnace slag or similar silicious material with slaked lime; not burned at all; usually hydraulic.

4. Natural (Roman-Rosendale) Cements: Made from impure clay, or magnesian, limestones; burned at low temperatures; will not slake with water, but must be pulverized dry; are definitely hydraulic.

5. Portland Cement: Made from artificial mixtures of calcareous and argillaceous materials; burned at high temperature to bring about partial fusion; require to be pulverized; strongly hydraulic.

Lime mortar has been in use from the earliest antiquity, traces of its presence being found in masonry far older than that of Egypt. The Romans discovered the hydraulic properties of the mixture of slaked lime and volcanic ash, and built from this puzzolan cement the aqueducts, sea walls, amphitheaters and foundations which have endured to our day. Apparently no progress was made beyond this puzzolan cement for about two thousand years, when Smeaton in England and probably some French engineers burned hydraulic lime and, by natural consequence, learned to make a crude natural or Rosendale cement. This was the beginning of the manufacture of cement in the modern sense.

The man who first made Portland cement did not set out to make it, nor did he even know that there was such a thing to make. He was simply gifted with the restless curiosity that is at the bottom of most material progress, and he tried some experiments just to see what would happen. His name was Joseph Aspdin, a brick-mason of Leeds, England. In an endeavor to improve upon the lime mortar with which he was familiar, he burned a mixture of clay and the dust from the lime macadam road and produced what he called Portland cement, which probably, however, was nothing more than a very crude natural cement of uneven quality and uncertain composition. He called it Portland cement for the reason that the artificial stone made from it was a yellowish-gray sandstone in appearance, resembling the stone quarried on the Isle of Portland, near the south coast of England. The real significance of Aspdin's discovery seems to lie in the fact that he first established the method of making an hydraulic cement by the mixture of two distinct materials, limestone and clay, and burning them at a high temperature. He probably did not, however, carry his burning to a sufficiently high temperature to bring about the partial formation of slag, or, as it is called in the modern practice, "incipient fusion." Aspdin made his first claims and took out his patent on Portland cement in 1824, and supplied cement in 1828 for the Thames tunnel. There was very little demand for his product, however, until in 1859 John Grant, engineer on the London drainage canal, decided to use Portland cement in its construction, for the reason that the concrete made from it was more permanent under water. By this time it is evident that the process had developed to the point of burning the clinker at a sufficiently high temperature to bring about incipient fusion, and the celebrated old works of White & Brothers, at Swanscombe, were already in operation and are

still existent. The Germans, however, applying their talents for technical research, made much better progress in the production of a uniform and reliable cement than did the English works; and from about 1860 until the end of the century the German Portland cements were better made than either the English or the French, and set the standard of quality in the trade. Since the beginning of the twentieth century, the American plants have been turning out the best Portland cement made anywhere in the world.

In the United States the first true Portland cement was made about 1875, by Captain Saylor and his associates, at Coplay, near Allentown, Pa. This cement was made from the so-called cement rock or clay-limestone of the Lehigh valley, a totally different material from that used in the European mills up to that time. Saylor's original plant turned out only 1 700 barrels of Portland cement a year, or probably from six to ten barrels a day. The output of the operating plants in the United States in the year 1912, thirty-seven years later, was about 70 000 000 barrels, or approximately 225 000 barrels per day.

The history of the little plant at Salt Lake City for the past twenty-two years comprises a fairly accurate epitome of the development of the industry throughout the United States, and it will perhaps be more satisfactory to describe the progress of the local plant with a little flavor of personal interest rather than to deal with the bare skeleton of the general progress throughout the country.

In 1885 the first cement was made in Utah in a small kiln erected in Emigration Canyon, near Wagner's Brewery. Later, in 1890, an Englishman by the name of Forester discovered in the canyons east of Salt Lake City argillaceous limestones and shales very much like those used in the Lehigh district for the manufacture of Portland cement. He interested sufficient capital to build a small plant for the manufacture of natural cement, among his stockholders being Mr. George Y. Wallace and Mr. W. P. Noble, still residents of Salt Lake City. The equipment of this plant consisted of a small stone kiln, lined with brick and braced with iron bands, into which the rock was charged in coarse lumps and burned with coal after the manner of the lime kiln. The calcined rock was ground up in buhr mills and the product found some local market, but the enterprise was not much of a success commercially, and the plant closed down after about two years' interrupted running. In 1893, a new company was organized, which undertook to make Portland

cement in a kiln built in the form of a great circular flue of brick, with a single stack at one side, the theory being that the process could be made continuous by charging the cement material into separate compartments in the circular flue, and firing them with coal in succession, so that the heat in a single compartment, being carried to a sufficiently high point to clinker the material, would, at the same time, heat the other compartments between it and the stack by the waste gases of combustion and bring about in this way both continuous production and a considerable economy in fuel. This is the so-called "Ring kiln" of the German mills; but in practice it was found very difficult to get a sufficiently high temperature to make a satisfactory Portland cement. In 1895, the Ring kiln was abandoned, and, after some experimental tests in a small shaft kiln, the company built what was then the latest improvement in the German practice, the Aalborg kiln, a shaft kiln about 90 ft. high, for burning the material in the form of bricks with the use of slack coal fed in at the lower third of the height of the shaft. This was a continuous kiln, being charged with the bricks at the top, fed with slack coal through openings in the side, and discharged through movable grates at the bottom. It made excellent clinker but was open to the objections common to all kilns of the shaft type, first, that the product was not uniformly burned, so that a great proportion of it had to be rehandled; second, that the labor cost was very high. The equipment of the plant with this kiln consisted of a small kiln for burning natural cement to be used as a binder in the bricks, a pug mill and brick machine, a drying shed and a ball mill and Griffin mill for grinding the clinker. This plant was entirely destroyed by fire in 1898 and was rebuilt immediately, using this time the rotary kiln, which was just becoming recognized as the standard appliance for this purpose. This first kiln was 50 ft. long and 5 ft. in diameter, and had an output of 100 barrels per day as against 50 barrels from the shaft kiln. This kiln did away entirely with the necessity of making the raw material into bricks, as it took the pulverized rock directly from the grinding mills and delivered it in the form of uniformly burned clinker in one process, and was continuous in action. The preliminary reduction was done with Dodge crushers, and the fine grinding with the Clark mill, a variation of the well-known Huntington mill, which delivered a finished product through screens self-contained in the mill. In 1902, the plant was extended by putting in larger kilns, 6½ ft. by 60 ft., and substituting tube mills, using pebbles, for doing the fine grinding on both the

raw material and clinker. In 1909, the plant was rebuilt again throughout, the present kilns being 8 ft. by 125 ft., and the grinding machinery consisting of rolls, ball mills and tube mills, the latter fitted with a slug grinding compartment at one end for increasing the fineness of the product. The equipment also covers a drier for the rock and another for the coal, a rotary cooler for the clinker, automatic weighing machines for the raw material and for the clinker, and the ordinary installation of conveying and elevating apparatus for passing the materials through the plant. The motive power consists of electric motors, for the most part individually connected with the several machines, there being practically no line shafting in the plant. The capacity of the present plant is 1 000 barrels per day as compared with 50 barrels per day in the original plant. And the change in the market conditions has been as marked, for when we made 50 barrels per day we sold it throughout a territory extending from Denver, Colorado Springs and Pueblo on the east, to San Francisco, Portland and Seattle on the west, and to Butte, Helena and Great Falls on the north; while now, with three plants operating in Utah, with a total output of more than three thousand barrels per day, the whole product is sold in Utah, southern Idaho and eastern Nevada.

Portland cement, chemically speaking, is not a definite product. We know the elements which enter into its composition within fairly close limits, but the true nature and proportions of the various combinations contained in the complex product known as Portland cement are as yet not determined with chemical exactness. The definition agreed upon by the American Society for Testing Materials, and recognized by the trade, is "the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than three per cent. has been made subsequent to calcination." The essential distinction, therefore, between Portland cement and other hydraulic materials is that it is distinctly an artificial product resulting from the treatment of the raw materials in a way which is not duplicated by Nature, either in the mixture or the burning.

As a matter of laboratory experiment, Portland cement may be manufactured, broadly speaking, from any materials which contain lime, silica and aluminum and iron in a fairly pure state. From the standpoint of commercial production, however, there

are numerous raw materials which contain these elements in a chemically pure or nearly pure condition, which are not adapted for making Portland cement on account of the physical difficulties to be met in securing a sufficiently intimate mixture of the elements; for example, a marble or calcite, which is practically pure crystalline carbonate of lime, is a very refractory raw material, requiring to be ground to such extreme fineness and mixed with the clays or shales with such thoroughness that the expense involved is prohibitive. The same is true of certain clays containing a large proportion of free silica or sand; chemically ideal in composition, they are physically unfit. Even at this, the range of the raw materials used for making cement is quite extensive. The original English plant used, and some of the English plants are still using, blue and yellow clays dredged from the river bottoms, and chalk from the soft chalk cliffs of southern and eastern England. The German plants use hard limestones, chalk and marl for the lime; clay, shales and cement rock or clay-limestones for the silica and aluminum. In the United States the majority of the plants use rock, that is to say, limestone more or less pure, shales and clays; but there are several plants in Michigan and Ohio, as well as the local plant at Brigham City, which use marls and clays: and the Universal Portland Cement Company, a subsidiary of the United States Steel, use their blast furnace slag as the clay element, mixing it with limestone, and making a true Portland cement. Generally speaking, it is more economical to use the amorphous unaltered limestones, and it is necessary that the silica should be present in combination and not as free silica, such as quartz or sand. These raw materials are so widely distributed throughout the United States and, generally speaking, throughout the world, that there is no possibility of any such control of the raw materials necessary for making Portland cement as to enable any combination, however extensive, to control its production by this means.

The original method of manufacture was to mix the chalk and the clay in an edge-runner mill with about 40 per cent. of water, making mud or slurry thin enough to be pumped or run by gravity through pipes. This mixture was run out into flat tanks, or "backs," as the English called them, allowed to settle, and the excess water removed by evaporation until the mixture was stiff enough to be cut into large-sized bricks. These were handled on pallets and dried in the sun, or later under sheds, and then loaded into shaft kilns and burned practically in the same

way as lime. As compared with the modern practice, this method seems extremely crude and enormously expensive in the matter of labor. It had, however, one advantage which is recognized in modern practice, i. e., the ease and certainty with which an exact mixture of the raw materials in quantity may be accomplished in the form of thin mud or slurry by the use of compressed air or mechanical agitation. Generally speaking, modern practice is divided into two broad methods so far as the preparation of the raw matrials is concerned. i. e., the dry process, in which all moisture is removed from the raw materials before they are ground or mixed, and they are then mixed and pulverized dry and delivered to the kiln in the form of a dry powder or dust; the wet process, in which the natural moisture found in the raw materials is increased as much as may be necessary to make the mixture flow readily through pumps and pipes, and the materials are ground wet and delivered to the kilns in the form of a slurry or thin mud. A variation, which is claimed to have advantages over both these methods, is what is called the semi-wet, or, by the Germans, the "thick slurry" process, in which only sufficient water is added to the raw mixture to permit of its being pumped through large diameter pipes and agitated by mechanical mixers, and delivered to the kilns in the form of a thick, soft mud, containing only about half as much water as in the regular wet process.

The essential features of all methods, so far as they concern the raw materials, are that the materials should be taken from the ground practically clean, that is to say, without the admixture of sand, sandstone, quartz, magnesia rock, alkalies, earth or other foreign substances which occur in connection with the deposits of cement materials; second, that the materials should be sampled with such thoroughness and regularity that their chemical analysis may be known in advance of their delivery to the plant and their relative proportions in the mixture adjusted by the chemist accordingly. This being accomplished, the materials are, as a rule, in the dry process, run through the preliminary drying and grinding before being mixed together, and are then weighed out by means of automatic scales according to the proportions necessary to give the proper ratio of the several elements in the raw mixture delivered to the kilns. In the wet process no trouble is taken to keep the two materials separate, and the preliminary mixing is done roughly by bulk rather than weight and the materials ground together from the first, the chemist relying upon the corrections which are easily and

accurately made by adding the requisite quantities of one or the other material to the mixture in the storage tanks and thoroughly blending it by compressed air or mechanical agitation. In both dry and wet processes, this mixture is ground, as a rule, through ball mills and tube mills to a fineness such that from 85 per cent. to 95 per cent. will pass through the 100-mesh sieve. It has come to be recognized as a cardinal principle that the fine grinding and intimate mixture of the entire mass of raw material are essential to the making of uniform and reliable cement.

From the moment the raw material enters the kilns, there is little distinction between the two methods of manufacture, the water in the wet process disappearing by evaporation in the heat of the kilns before the material has traveled more than a few feet. The modern kiln is a steel cylinder from 100 to 200 feet in length, and from 7 to 12 ft. in diameter, mounted on rollers, with an inclination of about one foot in twenty, and revolved by means of suitable gearing at the rate of from three-quarters to two revolutions per minute. The raw material fed in at the upper end travels down the kiln as it revolves and is clinkered at a temperature of from 2 300 to 2 800 degrees Fahrenheit by means of a flame produced either by powdered coal or fuel oil blown into the lower end by air blast. The clinker drops out at a bright red heat, consisting of rounded particles from the size of shot up to occasional lumps eight or ten inches in diameter, and is removed either by a rotary cooling drum directly under the kilns or by bucket carrier or drag to a cooler located some distance from the kilns; or again is dropped in an out-of-doors storage pile and left to cool by exposure to the air. When cool, the clinker, which is, in appearance, a hard, gray-black, porous slag, is mixed with from 2 to 3 per cent. by weight of raw gypsum, and is then pulverized to a fineness such that 95 per cent. or more passes the 100-mesh screen and 75 per cent. or more passes the 200-mesh screen. This is the finished product, and, if properly proportioned, mixed and burned, requires no further treatment or aging to render it perfectly stable and satisfactory in use.

The testing of Portland cement is done both by chemical analysis and by physical examination. The chemical tests are for the most part, limited to the determination of the composition of the cement itself and of the question as to whether or not it contains any adulterants. Physical tests form the basis for determining its quality from the standpoint of the constructing engineer.

The chemical tests, as ordinarily conducted, are limited to the determination of the silica, alumina, iron oxide, lime, magnesia and sulphur, and unless the undetermined residue runs over 1½ or 2 per cent. the cement is not considered open to suspicion of any adulteration, it being taken for granted that the undetermined portion consists of traces of potash or soda. The chemical analysis is conducted along the standard laboratory lines, usually by dissolving the sample in hydrochloric acid, and precipitating and filtering out the silica, alumina and iron, lime and magnesia in sequence. The proportions of the elements which make up a first-class Portland cement may vary within limits from one-half to as much as two per cent. without any apparent effect upon its quality.

An average analysis will run about as follows:

Silica	22.0
Alumina	7.5
Iron oxide	2.5
Lime	62.0
Magnesia	2.5
Sulphur trioxide	1.5

Variations in standard cements are indicated in the following.

Silica	12.28	25.38
Alumina	3.20	1.20
Iron oxide	6.36	3.34
Lime	59.66	62.96
Magnesia	3.11	1.20
Sulphur trioxide	1.40	0.35

The chemical analysis throws very little light upon the behavior of the cement in actual construction, and, in order to determine in advance its quality for this purpose, it must be subjected to the physical tests, which include specific gravity (this being taken as a check upon the thoroughness of the calcination), fineness of grinding, which determines the percentage of the product which is ground to a fineness permitting its prompt hydration and consequent set; the time of setting, which is important as governing the length of time available between the mixing of the concrete and its final placing in the work; the cold and hot water tests, which determine the stability or permanence of the cement after hydration; and the tests for tensile strength and resistance to crushing, which determine its

safe working load. The routine of the tests to which cement is subjected in the ordinary plant laboratory or in that of the inspecting engineer is as follows:

Ten grams of the cement is weighed and run through the 100- and 200-mesh screens and the residue weighed up to determine its fineness. A sufficient quantity, about 200 grams, is weighed out for making two pats and mixed with such a percentage of water by volume as will give the mortar a sufficiently plastic consistency so that it may be molded into pats, which will retain their shape, using a small trowel or spatula. The pats, placed upon pieces of glass about 4 in. square, are worked out to a thin edge and crowned to about three fourths of an inch at the center. These pats are allowed to set in a moist closet or under a wet cloth, and are used both for testing the rate of setting and also the stability. The rate of set is determined by placing the point of a loaded wire on the surface of the pat and as soon as the set has progressed sufficiently far so that the coarse needle, which has a point about one-eighth inch in diameter, ceases to make an impression, the cement is said to have taken its initial set, and record is made of the elapsed time. This test is repeated on the same pat with a fine pointed needle, to determine the final set. As soon as the final set takes place, the pat is placed on a rack in a tank in water which is brought to a boil, and subjected to the action of the boiling water for four to eight hours. The second pat may be placed in cold water and observed at intervals of one or more weeks, but this test is now used but little on account of the length of time required. The test pieces for determining tensile strength are made up both neat and mixed with three parts of sand; the mortar is placed in molds or forms shaped roughly like the figure eight, and having a cross-section at the narrowest point of exactly one square inch. These test pieces are allowed to set in moist air for twenty-four hours and then are placed in water for the remainder of the testing period. As a rule, the neat briquettes are broken at twenty-four hours, seven days and twenty-eight days, occasionally at three months, six months and one year for special tests. The sand briquettes are broken at seven days and at twenty-eight days, and also occasionally at the long-time periods. The breaking is done by placing the briquettes in clips and pulling them apart by a system of compound levers, like scales, the weight being gradually applied by a stream of fine shot. The crushing test is theoretically more correct than the tensile, seeming to represent actual working conditions in the majority of cases; but it is not as

commonly used for the reason that the apparatus required is both expensive and cumbersome. As a rule, therefore, the crushing test is carried out only in special laboratories and as a check upon the results of the other tests. There are a few old-time contractors and cement workers who still determine the quality of cement by certain other tests in which they have great personal faith, such, for example, as the taste, which has been described to me as an infallible guide to the presence of free lime, although I have never learned exactly what the difference is between the taste of a good cement and a bad one; also the color is considered an index of quality, the cement being required to show that "fine blue-gray color." As a rule, however, the foregoing chemical and physical tests are considered sufficiently conclusive.

The uses of Portland cement cover a very wide range, running from the filling of hollow teeth and the making of ornamental paper weights to making boats and signal buoys, fence-posts and telegraph poles, sewer and drain pipes, chimneys and smelter flues, and on to the heavy mass foundations for dry docks, sea walls, canal locks and reservoirs. Generally speaking, these uses may be divided into two broad methods, the use of concrete in mass, or monolithic concrete, and in combination or reinforced. Monolithic concrete is, of course, as a rule, employed only on mass construction of a considerable weight and thickness, such as footings and foundations, dams, retaining walls, pavements and roadways. The uses in combination are first in the form of mortar for laying up brick or stone work, or for plastering outside and inside on walls of other material. Reinforced concrete is applied both to the frame and to the walls, floors and roofs of buildings, to bridges, platforms, tanks for elevators and coal chutes, silos and stacks. There are also numberless secondary or special uses of cement concrete, such as artificial stones, hollow building blocks and all manner of ornamental castings. Some of this work is made intentionally to imitate stone, but it is becoming more and more common to use concrete straightforwardly as a material entitled to stand upon its own quality regardless of its resemblance to any other. Among some of the curious uses of cement are the plugging or sealing up of porous strata underground in order to shut off the flow of water in oil wells. For this purpose the cement grout is poured into the well and forced out into the seams of the rock by compressed air. Another interesting use is the making of very thin but rigid walls

and partitions by the use of metal lath and the so-called cement gun, which mixes and spreads a thin cement mortar by means of a compressed air injector working on the principle of the paint spray or coal injector. This device delivers a spray of cement mortar with such velocity that it is both spread and compacted at one operation, and with great thoroughness and economy.

It is natural that a material used in such a wide variety of ways and under such different working conditions should be subject to a great many abuses and should be the cause of a good many disappointments in ignorant or careless hands. The data for working out the proper design and arrangement for reinforced concrete construction are still rather unfamiliar to architects, and a good many engineers are reluctant to adopt reinforced concrete, in spite of its numerous advantages, through a feeling of nervousness on account of the lack of exact information and experience in its design. Most of the trouble, however, in the use of concrete arises from the fact that the average contractor and a great many engineers are rooted in the belief that good cement will make good concrete under any and all conditions, and conversely, that, if the concrete fails, the cement is always at fault. It is only necessary to point out that there are at least four factors in a piece of concrete construction, assuming that the design is correct, i. e., the cement, the aggregates (sand, gravel and stone), the water and the workmanship; but it never seems to occur to a great many users of cement to make any careful examination or inspection of anything except the cement, taking for granted that the other three factors are always satisfactory. If the engineers would insist upon examining the quality of the aggregates to be used, the character and chemical content of the water for mixing, and demand thorough and intelligent workmanship, the record of cement concrete construction would be free from a good many disappointments and discredits which, at that, are surprisingly few in comparison with the extent and variety of the abuse to which it is subjected. Two or three examples of this abuse will doubtless suggest plenty of others. A mining superintendent hauled forty sacks of cement ten miles up the mountain from the railroad to put in a compressor foundation and two weeks afterward was able to kick it out with the toe of his boot. Of course his inevitable conclusion was that the cement was no good, but upon investigation it turned out that the water used for mixing his concrete had been stored in old oil barrels and carried a sufficient percentage of oil and grease to completely destroy the set of the cement. A spillway or waste canal was lined with a six-inch

coating of cement concrete, and about two thirds of it disintegrated after four or five weeks. Here again the contractor could see nothing for it except bad cement, but it turned out that he had used the old tailings dump as the source of his sand, which, of course, was both convenient and cheap; but the tailings contained a considerable percentage of sulphides, so that upon oxidization they produced enough sulphuric acid to completely disintegrate the cement. A property owner has a wet cellar and his friend the contractor tells him that it is the simplest thing in the world to make it tight by putting a coat of cement plaster on the inside. It never occurs to either party, however, to thoroughly clean and soak the wall before applying the plaster, or to stop the flow of water at the point where it comes through the wall in order to give the plaster time to set. Consequently the plaster fails to stick to the wall and the water comes in as strong as ever, and both the contractor and the house-owner are satisfied that cement plaster is no good.

DISCUSSION.

Mr. Bacon remarked that up to about ten years ago but little attention was given by engineers to the design of concrete structures. The following five years the designers went to extremes, not making proper allowances for strength of material, the past five years seeing a return to safe designs, with the larger contractors taking up the laboratory investigations where the students left off, in order to get the best possible results from all materials.

Retrogression in tensile strength as developed by neat tests: Mr. Ronk brought up the point of the drop in tensile strength shown by neat tests between the seventh and twenty-eighth days. Most specifications designate certain limits for the seventh and twenty-eighth day tests, but should they have a right to object to fluctuations in the strength between those days? The plotted curves of various tests show that there is no cement on the market but shows some drop during this period. This action develops only in the neat test, the sand tests showing no drop. The drop in tensile strength is attributed to the aluminates losing their strength before the silicates develop theirs.

Mr. Pierce in personal test found that high lime cements actually increase in strength from the tenth to seventeenth day.

Failures in Concrete: Mr. A. B. Villadsen brought out the fact that the people only heard of the failures and in nearly all

such cases the cement is blamed, instead of the aggregates, or the improper mixing, etc. One of the first requisites for good concrete is clean, sharp sand; in many cases the washing of poor sand will give good results.

Mr. Goodrich said that while a great deal of attention was paid to the tests of cements in the western country, as much attention should be paid to the aggregates, and especially the quality of the water, as in many places the minerals carried in the water are adverse to proper setting of the cement. Tests of the various sands in the vicinity of Salt Lake show that the high bench sand, though dirty, is the strongest.

Mr. Randall found by tests that sands carrying up to 15 per cent. loam gave the same results as average clean sand.

Mr. A. B. Villadsen mentioned another common source of failure in the handling of concrete, especially reinforced, that is, removing the forms too soon. More attention should be given to the temperature at the time of placing; as where concrete is placed during the summer, the forms could be removed after two weeks; in the winter season with temperature below 40 degrees, it would have hardly set. He believes that in making calculations for the time for concrete to set days having temperatures below 55 degrees should not be counted.

Mr. Brown remarked that grading of the aggregates to reduce the percentage of voids was essential to good concrete, and also that depositing concrete during freezing weather was not necessarily fatal to the mixture, providing it froze before the initial set, but freezing afterwards was not good.

Failures are quite often due to the poor quality of cement. This may not develop at the time of testing on account of wrong methods or lack of care in making tests, or even the personal equation of the tester. The amount of cement used in the sieve test as practiced in this district is 10 grams, while some believe in using from 25 to 50 grams.

While it was generally understood that cement standing the boiling test should be entirely safe, Mr. Pierce stated that in tests conducted by him that showed a tensile strength of from 1 000 lb. to 1 200 lb. at seven to twenty-eight days the cement went to pieces in six months, and that a shipment of 10 000 barrels failed to meet the requirements after passing all tests, including boiling and steaming, the tensile strength dropping over 25 per cent. More attention is being given to the long-time tests as corresponding more nearly to the actual conditions in construction.

Mr. Davis spoke of the tests made by the Engineering Department of the Oregon Short Line Railroad Company on cement mixed with water from Great Salt Lake. The mixture tested showed average results in initial set and on the seventh and twenty-eighth day tests, but had no tensile strength at the end of six months. These tests showed some retrogression between the seventh and twenty-eighth days.

In answer to question of Mr. Goodrich, regarding the use of the cement gun in placing cement on tunnel linings, etc., Mr. Sheley stated that it was used with success in the construction of the Little Salmon River Dam in southern Idaho. For results obtained, communicate with Mr. F. C. Horn, of Boise, Ida.

Various points suggested by the subject were further discussed by Messrs. Sullivan, Brown, Dalton, Sheley and others.

[NOTE. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 15, 1913, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER, "MISAPPLICATION OF INTEREST, CONTINGENCIES AND ENGINEERING ITEMS FOR VALUING RAILROADS BY COST OF REPLACEMENT METHOD."

(VOLUME LI, PAGE 95, AUGUST, 1913.)

MR. F. G. JONAH.*—The writer notes in the August number the JOURNAL an explanation by Mr. Jurgensen as to why he terms the items of "interest," "contingencies" and "engineering" as fictitious and imaginary in estimates of the Reproduction Cost of Railroad properties. The theory is advanced that since there is to be no actual reconstruction, these items should, therefore, be left out of the estimates.

It is not clear why these items should be so treated, as in an estimate they bear a proper relation to the total cost, the same as items for grading, rail, ties, ballast, etc. Engineers make estimates frequently for lines which may or may not be built. Their estimates are not varied in any respect by the possibility that the line estimated upon may not be built, and any such estimate, if made by a competent engineer, will carry an item for interest during construction, for engineering, and for contingencies.

The mere fact that different engineers will use different percentages for the items of engineering and contingencies is no proof that the subjects should be left out of account.

Mr. Jurgensen says, "The item 'engineering' is also a purely fictitious one, except when used in connection with and as a part of *actual* construction cost." The writer contends that it has a proper place in any estimate, whether it be for work that has been done or for work yet to be done, and the experience of engineers enables them to estimate this item with a very close degree of accuracy.

As to "contingencies," Mr. Jurgensen says, "As there was to be no actual reconstruction of the property, no contingencies could be encountered." This is no proof that contingencies were not encountered in the construction of the line on which reproduction estimates are being made, and no reason for leaving the item out of the estimates, and that contingencies can be measured from profiles or other records is a statement with which few engineers will agree.

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* Member Engineers' Club of St. Louis.

Mr. L. S. Pomeroy.* — The writer fails to see where Mr. Jurgensen has said anything in support of the main contention originally stated in the following language:

"Having found a false and excessive value for the items inventoried, allowances were added for interest during construction, contingencies and engineering. These items are purely imaginary and, being illusive, their measure depends upon the ability of the appraiser to imagine." (Association Journal, Vol. 49, page 211.)

In answer to this Mr. Jonah says, on page 67, Vol. 50:

"The men who finance railway projects do not class interest during construction as an imaginary item."

And, notwithstanding all that is said by Mr. Jurgensen in the paper under discussion, it appears to the writer that Mr. Jonah's point is uncontroverted.

Mr. Jurgensen now says, "The position I took was that, the reconstruction being fictitious, interest during construction was equally fictitious or imaginary and depended for its amount upon the caprice of the estimator."

By substitution of the word "opinion" for "caprice" in the closing sentence of the foregoing paragraph, the writer is in accord with the sentiment therein expressed, but must emphatically dissent from that earlier expressed, that the item of interest in itself is imaginary and should have had no place in the inventory. Mr. Jurgensen's reasoning seems to be that because the item of interest is indefinite and, by using the imagination differently, different amounts for it may be arrived at, any amount is necessarily excessive and should be striken out. With this sentiment the writer cannot agree. He knows of no process of mathematics by which it can be proved that if, by following one line of reasoning, $x = 23\,000\,000$, by another, $x = 39\,000\,000$, and by a third, $x = 164\,000\,000$,—x must necessarily equal zero. Why not as properly say that any other item whose value had to be estimated should be striken out?

In the four pages devoted to the subject of interest, the writer fails to see where there is a single word said in support of the main contention that the item of interest during construction is purely imaginary.

Coming to the subject of Engineering, Mr. Jurgensen says,

"If the problem was to ascertain the original cost of con-

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struction, and we had only a statement of the number of yards of material and other items involving construction, together with the prices paid for the work and material, it would be eminently proper to add an estimate for engineering expenses, but no such problem is involved. *There is to be no construction.* [Italics ours.] The item as used, is, therefore, purely fictitious, and has no place in the inventory."

It is extremely difficult for an unprejudiced mind to see the logic in this. Why because there is to be no actual construction is the item of engineering any less a part of the hypothetical construction than are the items of grading, track laying and surfacing, etc.? Following Mr. Jurgensen's line of reasoning, these, too, would have to be stricken out.

It seems to the writer that a decidedly better argument for eliminating such engineering as is incident to construction would be to say that it had been taken care of in the amounts allowed for grading and track laying and surfacing; but how about the reconnaissance, preliminary and location surveys which sometimes cover a period of several years before the line is actually built? Are these no part of the cost of the road? It would seem that for a man in Mr. Jurgensen's position to reason thus shows a decided lack of knowledge of railroad construction.

With regard to the item of contingencies, the writer will admit that there is merit in the contention that as far as sinkholes are concerned, these may have been taken care of in the amounts allowed for grading. But are these all the contingencies that may have arisen? Is it not possible that there have been considerable stretches of partially built embankment washed away, trestles rebuilt, and similar occurrences of which there may now be no record?

The writer personally knows of a piece of construction in Indiana where a bridge abutment had to be entirely rebuilt and another bridge very materially altered on account of conditions that the wisest engineer could hardly have foreseen.

Such circumstances, it seems to the writer, justify a moderate allowance for even this most imaginary of items, and it further appears from the numerous articles that have been written of late on this much-discussed Cost of Reproduction New Doctrine, that the engineering profession generally can hardly be in accord with Mr. Jurgensen.

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THE PROBLEMS OF THE CONTRACTOR.

BY LEONARD C. WASON, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, September 17, 1913.]

INTRODUCTION.

THIS paper is written at the suggestion of a friend, an engineer of wide experience and ability in the design and superintendence of construction of buildings, who believes that if the engineer and the architect can better understand the problems they put up to the contractor, and can get an insight into the *whole* problem through his eyes, greater efficiency will be obtained in building operations and more harmony in their business relations will result.

The writer believes most positively that an engineer and a contractor are both necessary. That no matter how great the ability in every direction of any one person, and in spite of unlimited help and financial resources, the owner's interests in the long run can better be served by two persons — the engineer and the contractor — working together than by one alone performing all these duties.

Holding the above views, the writer wishes to make it clear that no criticism of engineers and architects is either made or intended in what follows. There are some plain statements of facts, however, made to illustrate the contractor's point of view.

If this paper helps to establish permanent team work, where there is now too frequently antagonism and misunderstanding, it will have justified its existence.

The company with which the writer is connected has for nearly twenty years specialized in reinforced concrete. In the

past it has executed work of every kind in which Portland cement is largely used, but during the last few years nearly every class of cement work has been dropped except building construction. Mills for various industrial purposes have constituted the major part of this work. The goal the company has sought by thus specializing and concentrating is to be able to erect a better building, in quicker time and for less money, than any other concern in this part of the United States. It will be seen in what follows that the day of the contractor whose only written record is a pocket time book and the stubs of a check book has passed, and that somewhat intricate methods and elaborate organization have taken his place. This organization and the methods used are of slow development. It is hoped to prove that in solving the contractor's problem of furnishing quick, efficient and economical service the results accomplished justify the methods employed.

Everything described in this paper is from the personal experience of the writer and of his company. In order to lay bare as clearly as possible the activities, duties and work of the contractor treated in the second subdivision of this paper following, it has been found necessary in a few instances, in order to illustrate a point, to describe a specific experience, but otherwise only the fundamental methods applying to the execution of any job are discussed.

The subject is considered in two parts. First, the human element; and second, the mechanical features of actual construction. For convenience both parts are subdivided, as follows:

Human Elements.

General relations: With owner; with engineer; with inspector. The superintendent.

THE CONTRACT.

Execution of Contract — *Mechanical Elements.*

Preliminary work.

Analysis of the design: Minor features; uncommon features; method of drawing details.

Selection and purchase of materials.

Management of Construction.

Drawings for forms, steel bending and plant.

Plant: Kind, amount, arrangement, methods.

Organization of job force.
Planning, routing and cost accounting.
Weather conditions: Precautions against rain, sun and frost.

General Relations.

Before taking up the mechanical elements of executing a contract, it would be well to consider the human element in the problems of the contractor, an element which is sometimes paramount to the actual execution of a contract.

After learning that there is a prospective job, a member of the company investigates its character and location, to determine whether it is within the company's specialized work, and whether it is desirable. He then meets the owner if possible, to interest him, and to size up his temperament and business methods.

The Owner. — As sometimes the owner takes an active interest in the execution of the work, although he deals through his engineer or architect, it is of considerable importance to know his temperament and point of view. Greater harmony will thus be obtained. The engineer will do well to bring both parties together early and often. There is the owner who has not been seen at the time of final payment, and the one who is in evidence every day, — the one who has a technical training and knows, and the one who does not know about construction, but thinks he does, and personally mixes into the work commonly considered as the engineer's. If the engineer is weak-kneed, with the last-named type of owner, expense and misunderstanding are almost certain to result, primarily because no man can serve two masters, and secondarily because an ignorant master, the owner, is never satisfied. If there is a very strong, fair-minded engineer who commands the respect of his client, there is little trouble with any type of owner.

The worst combination is a fussy owner and an engineer who has obtained his commission by hard chasing, instead of through the owners going to him. He is the hardest to control and makes trouble for the contractor that affects the cost of the work. The contractor, therefore, seeks to learn the probable conditions before submitting a bid.

The Engineer or Architect. — Then it is necessary to study the engineer or architect and consider his method of handling and supervising work. The methods of some engineers are radically different from those of others; this has a marked bearing upon the cost of the work and sometimes on its desirability to

the contractor. The contractor must determine what sort of treatment he will receive. Nothing adds to the price of a bid like uncertainty, whether it be in the temperament of engineer and owner or in unknown construction problems.

In one case where a number of local firms were invited to bid on a certain large building for an architect who was well known always to rule in favor of his client, irrespective of the merits of the case, the successful bidder, after figuring full measure on all quantities, added this item, — "Humor architect"; the item was 10 per cent. of the contract. It is safe to presume that all other competitors placed this contingency at a higher figure. Such a man could not get a reasonable bid from any one who knew him, and he certainly could not expect to let work advantageously to guileless strangers. An engineer in a distant city whose reputation has reached beyond the limits of his activities has a personal equation of 25 per cent. plus. The best information available indicates that these men do not personally profit in any way improperly in this excess cost. Instead of being wise and just judges between the two contracting parties, they are simply over-zealous partisans. Fortunately this class of architect and engineer is very small and their influence on industry still smaller.

The largest class is that in which the engineer or architect intends always to be just, but on rare occasions allows his judgment to be influenced by the attitude of the owner; or, where two different solutions may be possible, for policy's sake or for hope of personal advancement, makes the second best decision. This increased expense which is entailed can never be foreseen, although it certainly exists and has to be paid for as a contingent item of cost. The reputation of the engineer who is always fair spreads far and wide, and he is sought out by many responsible contractors who desire to do his work. This results in work being done at the lowest legitimate cost by competent firms; the owner gets a square deal, continues himself, and also recommends his friends, to employ this engineer, who in the long run prospers more than he could by other methods. Meanwhile, he maintains his self respect and is justly proud of work well done.

Contractors talk rather freely among themselves about their experiences and their opinion of those for whom they have worked, and perhaps oftener than is imagined are asked by owners whom they would recommend to design new work. They certainly exert an influence on the reputation and also on the business of the engineer.

The Inspector. — One of the great problems which the contractor has to face is that of the inspector who represents the engineer on the work. A thoroughly competent inspector is a great help to the contractor and very beneficial in the results obtained. An incompetent one is exactly the reverse. The writer recognizes the difficulties the engineer labors under in selecting his inspector. The duties are not hard, and to the man with ability, ambition and push, the close confinement to long hours of attendance on the work with little to do except keep his eyes open is too irksome to be long endured, even at a good salary, and this desirable type soon moves to what he considers better employment. The most impoitant thing to consider in the appointment of an inexperienced man is his temperament. He must have an even temper not easily ruffled, be considerate, yet firm, always diplomatic, and be capable of performing his duties acceptably to his employer.

The superintendent for the contractor is necessarily better informed and trained in construction, an executive who is constantly directing others and quick to resist for the good of the service insubordination or usurpation of the duties for which he is held to strict account by his employer. In other words, he is trained to be an autocrat. This temperament does not take kindly to being bossed by a younger man admittedly with less experience. Therefore, the inspector must have the above-named qualities and also must not consider it a personal affront when his orders are overruled. He will make some mistakes which the engineer will correct, and many more, alas, which his chief will never hear about, although they make unnecessary expense and may affect his chief's professional reputation. He is put in a trying position, left too much alone, and required to perform certain duties, but he must not go beyond bounds.

Friction is most frequently caused when the inspector assumes to perform duties which do not belong to him. The contractor has a perfect right to object to this, but out of the refusal grow many complications. Judging from results, the inspectors are not concisely instructed in their duties and they are not watched closely enough by their chiefs to see that they not only perform their duty but also do not attempt to perform more. The most common mistake of the inspector is to interfere in the conduct of the work by giving the workman orders direct. To permit this would destroy the morale and disorganize the job with far-reaching consequences. A few personal experiences might be quoted to illustrate the point.

On a job for a branch of one of the large so-called trusts, the inspector was a gray-haired man who had had years of experience as an architect, manufacturer of brick, and as a builder, and was reputed to be receiving pay of $75 a week. He considered himself a better designer than his employer and made new elevations for the building. When the superintendent of the job declined to follow these until the architect had approved them, he was offended, found fault with the methods used and with the work, tried to give orders to the workmen, and interpreted the specifications to the disadvantage of contractor. The fault here was the inspector overreached his legitimate duties, and then had not the discernment to see that to follow his unauthorized plans would be a breach of contract. He took it as a personal affront that his ability and design were not appreciated. Happily, he later changed somewhat, worked in coöperation with the superintendent, and was more than pleased with the ultimate result. Moreover, exceptionally low unit costs were obtained on the work.

The inspector appointed for political purposes is a thorn in the flesh. In one case where a granolithic sidewalk was being laid for a city, an incompetent inspector had a tar concrete specification as a guide. Because the work didn't agree, he ordered the foreman to stop. There were differences of opinion and words, finally the foreman was arrested and locked up, causing the writer considerable trouble in straightening the matter out. Another city inspector demanded a cash payment before he would pass a sidewalk pavement.

On a job for the state a transitman was appointed to inspect some granolithic paving. He was thoroughly conscientious and honest, but entirely ignorant of the work he had to inspect, and thoroughly suspicious of the contractor. The cement was delivered on the job in bags, which was a brand new proposition for the inspector. He would not take the writer's word for it that four bags made a barrel. There were no Portland cement barrels available, as the work was in a rather inaccessible country place. However, with considerable difficulty he found a natural cement barrel and insisted upon the cement being dumped from the bags into this barrel to be measured. In this loose state it took only three bags to fill the barrel, and he insisted that only three bags should be used in a batch instead of four. Realizing that the work would fail and that there was a five-year guarantee on the work, the writer insisted on using the four bags. The inspector did not wish it. The difficulty was overcome as

follows: There was one longitudinal joint in the work which the inspector learned that his chief desired to have absolutely true and straight. An extra man was put on the job to set up and knock down the curb board for this joint during the forenoon, while the inspector was squinting through a transit at the far end to line it up. Meanwhile, the concrete for the day was being mixed and placed from the opposite end of the job. After more than sixteen years, the pavement is in perfect condition.

The above cases are typical of a great many that have occurred in the writer's experience. They illustrate how variable a problem the contractor faces. Any one engineer as a rule selects a similar type of inspector so that after the second job this item can be fairly well forecast.

It may be asked why the contractor so seldom protests against the rulings and objections of incompetent inspectors and those who have an alleged grudge to work off, and appeals to their chief. Experience has proved that the firm which habitually does this would find it much more profitable to retire from business.

The Superintendent. — The very first step which a contractor must take in starting the execution of a job is selecting a general superintendent to handle the work. The type that is hired for a single job and discharged at its completion is not worth having. The really desirable superintendent is a development from experience, the one survival from many tried, and when once obtained a firm cannot afford to lose him. Some owners and engineers appreciate the value of personality so much that they have given the writer's company contracts under condition that a certain superintendent be put in charge.

Frederick W. Taylor, in his excellent paper entitled "Shop Management," specifies nine different qualifications which go to make up a well-rounded man, namely: "Brains; education; special or technical knowledge; manual dexterity or strength; tact; energy; grit; honesty; judgment or common-sense; and good health." He states that there are plenty of men to be found who embody three of these qualifications. Four make a higher-priced man. A man combining five is quite hard to get, and one combining six, seven or eight is almost impossible.

If a building superintendent is to be successful, he must combine at least seven of these qualities. He must have brains, special and technical knowledge of both direct contract and subcontract work, tact, energy, honesty, judgment and good health. He must have a personality which drives to activity several

hundred originally unorganized men who are without special interest in the company they work for or in the result accomplished, and with such tact and judgment as to weld them into a harmonious working force, cheerful and self-respecting, with high morale, and ultimately with enthusiasm for the work in hand. He carries a care so great that he builds in full size, with permanent materials, the intricacies of design which trouble the engineer's drafting room to show clearly on paper; with an honor so fine that the company is ready to leave its reputation in his hands, to trust him with funds; and with special experience so trained that dangerous operations are carried on as a matter of routine, without worry to himself or the company, yet with a constant oversight of a thousand chances for accident or perhaps death which may occur to the men in his charge; with a forethought so great that he sees ahead and provides for the problems which are to come up perhaps months later; with a temper so good that he never loses self-control under the most provoking circumstances, and is able to take with the best of grace changes in his plans from the office, and to work in the close coöperation with the company which is so necessary to make it an effective contracting organization.

Such men have a temperament that responds quickly to criticism or praise. Praise comes sparingly, even when deserved, while criticism is freely meted out. Superintendents in the employ of the company have recalled to memory words of appreciation from an owner or an engineer long after the job has faded from the writer's memory, and he has seen a man's work improve in quality and cost purely through praise for some detail of the work which was ably handled or some difficulty which was ingeniously overcome. The company, including its superintendents, feels as much pride in the jobs it does as do the engineers who have designed these structures. The members of the executive force on any job which is sharply criticised will try to avoid criticism by refusing the slightest responsibility beyond what they believe to be clearly their own. A company sharply criticised by an engineer is likely to do precisely the same thing and will throw on to the engineer every bit of responsibility which it can possibly avoid. The attitude of the engineer in this respect is reflected in the execution of the work. One engineer may call attention to a mistake with a letter that is harsh and ends with a sting, which leaves the feeling of injustice and soreness in the recipient. Another, in calling attention to a similar matter, ends his letter with some expression like the following: "We appreciate your

wish to make this work as satisfactory as possible, and recognize that this occurred through failure to understand my exact requirements." In response to such a letter as the first, the tendency is to do just as little as will satisfy the engineer and take your own time about it. But, as the writer knows from personal experience, in response to the second letter, you jump to correct the trouble cheerfully, quickly and without comment, and also sometimes do more than was asked for.

The engineers for whom we have done the best, cheapest and the most cheerful work have uniformly trusted us, have assumed that mistakes which we made were excusable, have coöperated with us to untangle difficulties which we have gotten into, and have been appreciative.

The problem in selecting the superintendent which the contractor must consider, is whether in the particular location he will be able to handle the difficulties which arise. There are superintendents who invariably command the complete confidence of the owner, no matter what his disposition may be, who always get along nicely with the engineer and his inspector, although they may be lacking in some other qualities which are desirable. Perhaps the owner and engineer desire an exceptionally fine appearance in the finished mill. One superintendent is especially good at this. Perh ps finish is of no great moment, and business ability is, on account of the job being isolated so that the superintendent is left alone for some days at a time.

Perhaps the local conditions may demand a great deal of tact by the superintendent in the handling of his labor. The following illustration shows what tact is required. When the writer's company executed its first contract in Buffalo, it was for a firm which had had considerable trouble with labor and it was anticipated that there would be a strike before the job was very far advanced. This firm had been marked by the local labor organizations as their natural prey, and these organizations were also prejudiced against outside firms coming into their territory. The carpenters there have a strong organization. During the early stages of this job, while there were but a few carpenters, the superintendent could give them considerable personal attention and things went smoothly, but as soon as work began on the second floor where they could not be so easily seen and the superintendent was too busy with other matters to watch them closely, unit costs began to climb day by day. The superintendent studied the situation to find the cause. By the time form work was starting on the third story he became con-

vinced that the union teward of the job was to blame and was holding the men back from doing their best. The natural impulse would have been to discharge him immediately, but that would have made hard feeling with the union. The superintendent took this man aside, confided to him his troubles, and then made this man sub-foreman with entire charge of erecting forms for columns, which was the particular item which showed the highest cost. Immediately the costs came down, and on the fourth story were the lowest on the whole job. The result was saving a thoroughly first-class workman and keeping in the good graces of the local organization. Some years have gone by since, and there has been no trouble whatsoever with the labor situation in Buffalo. Such tact and forbearance are frequently demanded of superintendents, and they are usually equal to the situation.

These various questions must be weighed and settled before a start is made. Experience has shown that after a job has once started with a given organization, a change in the superintendent is the cause of much disturbance to its satisfactory completion and economy in the handling of labor. It is of the most vital importance that this question be settled rightly once for all.

The Contract.

The type of contract is manifest'y of considerable importance. It is the firm opinion of the writer that the usual type of lump sum contract obtained in competitive bidding does not give an owner the best results. With competitive bidding open to all, the lowest bidder is liable to be one who does not use the best of methods, is looking for all sorts of short cuts, and is frequently one with a limited amount of experience and capital. It has been often noted that those new in the reinforced concrete field underestimate the difficulty and cost and do work badly at first, no matter how experienced in other lines. The lowest bidder is squeezed to a figure where it is known he cannot make much, if anything, and there is every incentive to save and slight. This condition of necessity encourages mutual suspicion and antagonism before the start; therefore, the best results are impossible. No amount of careful inspection can make an inexperienced or incompetent contracto turn out thoroughly first-class work.

On the other hand, under the cost-plus-fixed-sum-for-profit type of contract, the interests of the owner, builder and engineer are one. Work obtained in this way is certain to be much

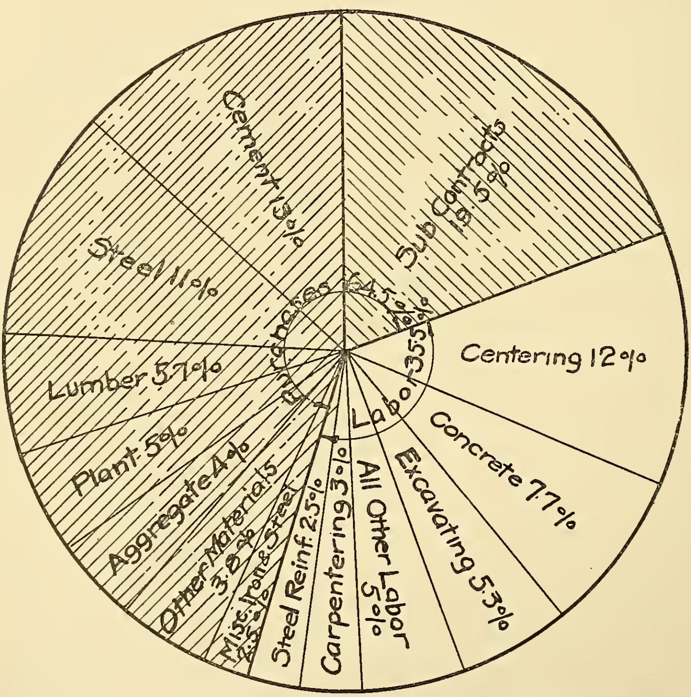
better for the same cost; even if the cost is slightly greater, the owner has the assurance that he is getting much more for his money. The majority of manufacturers whom the writer knows look upon a mill building as a tool to be used in a manufacturing process, rather than as real estate, and want to get a thoroughly first-class tool rather than the absolute last dollar knocked off the first cost of real estate, and, therefore, believe the extra cost justified. The engineer can examine the estimate of cost as prepared by the contractor, discuss savings or changes, and can see places where he is willing to cut the design, when he knows that there is not going to be still further cut in the execution of the work. When he knows that the work is going to be executed exactly as designed, he can design with greater precision and economy than when he has to provide extra strength or size of members to allow for a possible lack of quality of materials and workmanship by some unknown person who may have the execution of the work in hand. The work can be carried on also much faster under this method of close coöperation than under the other, where there are likely to be misunderstandings which must be adjusted before the work progresses further. What the contractor has to sell is service, and what the owner wants is results, and where this mutuality exists both parties can accomplish the end which they are striving for.

The conservative contractor figuring on a lump sum contract includes everything shown at a price he feels sure he can do the work for; then, as every emergency cannot be foreseen, he allows an item for contingencies, and finally adds a percentage for use of capital and profit. Under a fixed profit contract, however, where the contingent risk is assumed by the owner, a lesser profit will be accepted by the same contractor because it is assumed, while the total cost may be reduced by coöperation between contractor, engineer and owner in the matter of design and the purchase of materials. Under average conditions a saving as great as ten per cent. may be made. The specialist will obtain lower unit costs on the work than a less experienced man who is liable to submit a lower competitive bid. This is why the same quality of work can usually be done at less cost to the owner under the fixed profit basis and why a very material improvement in quality can be secured with very slight increase in cost.

If the owner wants to start as soon as he engages an engineer and before plans are started, he can save about six weeks' time with no serious difference of cost on the cost-plus-fixed-sum basis.

There are several variations in details with this type of contract. Its merit lies in removing one of the most trying problems of the contractor, — his antagonistic relation to engineer and owner.

Because the handling of reinforced concrete is to a large extent a manufacturing proposition, it is obviously more desirable to let such work to specialists than to those experienced only in the erection of ordinary brick or wooden buildings. In the making of concrete a number of crude materials are brought together and treated in such a way as to produce a new one, whereas in the construction of a wooden or a brick building, materials are merely assembled, but are not changed essentially after they are in place from what they were before. A manufactured article is either right or wrong, and if wrong must either be accepted as such or entirely destroyed and new material



ANALYSIS OF COST
ABERTHAW CONSTRUCTION CO.
BOSTON, MASS.

FIG I.

manufactured in its place. Therefore, where the difference in cost is small, it is much safer for an owner to take no chance on how his building will be manufactured.

The engineer and owner do not sufficiently appreciate that the builder or contractor is largely a broker buying materials. With an office building, for instance, the general contractor may not handle more than ten per cent. of the contract price as direct labor. The rest is materials bought and subcontracts let. With reinforced concrete, the percentage of labor is larger than in any other building operation. It averages about 35 per cent. of the cost. The contractor, therefore, realizes the necessity of a first-class purchasing department. Most manufacturers have such a department. Sometimes one and sometimes the other has much better facilities for obtaining the lowest price on materials required in construction. Therefore, the coöperation between the two departments produces the best result to the owner. A diagram of the results obtained on a recent building is given to illustrate the important divisions of cost.

Preliminary Work.

While the estimating department is busy scaling plans and computing quantities, the writer or an associate examines the site of the proposed structure, calls upon various parties who can give information useful in the preparation of an estimate: such as municipal authorities, for information as to local regulations, the customs department and immigration bureau, if job is in Canada, dealers in all the principal building materials required, and the contractors for the principal lines of subcontracts, such as carpentering, plumbing, roofing, painting, sheet metal, bricklaying, etc., also dealers in contractors' machinery of various kinds. He visits the engineers of the local railroad, whose main line adjoins the site of the work, when it is proposed to install a siding, as the time of its completion is important; also the general freight agent in regard to rates on material at this point. General contractors, and all others, who would have any information regarding the labor situation are consulted. From the data thus obtained, and by studying the unit costs of completed jobs which somewhat resemble the one in view, prices are determined for use in an estimate to be submitted to the engineer.

Analysis of the Design.

When a contract is awarded, and a set of plans received from the engineer, a considerable amount of work is done in the main

office, beginning long before any work is started in the field, and continued during the early stages of construction, in two departments — the designing and the purchasing. The designing will first be considered.

The function of the designing department is to take the complete set of plans and make a careful study of these in regard to designing forms, tabulating steel, and illustrating and tabulating other materials, such as doors, windows, architectural iron, etc., where this is not done in the engineer's office. The location of construction and contraction joints is studied, and on rare occasions the structural design is reviewed. In the writer's practice it is common to close a contract and start building before any working drawings are made. Then the work and responsibility thrown on the designing department are very great. Also some of the below-mentioned minor features become major ones and are, therefore, discussed here as though they were.

No attempt will be made to describe ordinary designing for strength, but rather those features which are not usually shown on plans, and others which a contractor desires to change for the sake of economy, simplicity in construction, avoidance of cracks, etc.

Minor Features. — This term is applied to those parts of the designing which are not vital to the construction, and, therefore, frequently are not shown on plans, being left either to be settled in advance by the builder or during construction by himself and the engineer. Some of these points are learned only by experience in actual construction, and may not have occurred to the engineer until called to his attention.

Chief among these minor features to receive attention are the means to be provided to prevent cracks, which mar the appearance and are often a source of annoyance though seldom a cause of structural weakness. There are, sometimes, cracks caused by unequal settlement of foundation. Sometimes a part of a building is on piles and part on earth. Where they join it is hard to foresee and provide such an amount of bearing that the whole will settle evenly. It is usually best to provide a broader bearing on the less rigid material than theory dictates, then unsightly cracks may be avoided by very rigid tying of the building together with reinforcement, against pulling apart longitudinally or shearing. This requires both horizontal and diagonal reinforcement with a minimum quantity, equal to at least one-half of one per cent. of area of concrete. A somewhat larger amount is preferred.

Another way to overcome the same difficulty is by building a joint vertically clear through the structure at this point and designing the members of the structure on either side so that, if settlement does occur, they will not crack. This was done with satisfactory results in a recent building where one end rested upon sand, the center on ledge and the other end on clay.

Large wall surfaces without joints are very liable to crack vertically, due to the shrinkage stresses of the concrete. Experience has shown that thin walls with insufficient reinforcement will crack about every twenty-five feet of their length where exposed to the air on both sides. Thick walls will crack about every fifty feet. Where the wall is exposed to the air on one side only, and kept at a fairly uniform temperature, either by water or earth on the other side, there is very much less danger of cracks in any length.

Temperature stresses do not have to be considered by themselves. The writer has not met a case where the structure could change its temperature so rapidly as to crack from this cause. If properly reinforced against shrinkage cracks, the temperature stresses will be sufficiently provided for.

Walls of buildings 400 ft. in length, which have been built without joints, have not developed cracks. However, the amount of steel used, in the writer's opinion, was not justified on the grounds of economy or in comparison with the result obtained. In such a wall internal stresses are very likely to open diagonal cracks, radiating from corners of windows and doors; therefore, diagonal reinforcement is necessary at such points. This is seldom shown on plans when received.

On the ground of cheapness of construction, it is almost always better to put curtain walls in after the frame is up; the work then goes ahead much faster. Weather-tight joints can readily be made, and the joints between the frame, that is, the columns and floor, can be concealed so that no unsightly crack is visible.

Where a floor is built around machinery foundations, frequently a long span and a short span beam come close together. Unless provision is made for a joint between them, there is certain to be an unsightly crack, due to the difference of deflection of the two under the same load.

Another point of design which may sometimes be advantageously discussed by the engineer is that of roof construction, whether the structural part shall be flat and covered with

cinders, to give a proper pitch for drainage, or whether the ceiling shall be pitched and the fill avoided.

In construction the most serious objection to the first method is that so much time elapses between the casting of the roof and the waterproof cover of tar and felt over the cinder fill that a considerable quantity of rain collects on top of the roof slab. These slabs, while not absolutely watertight, are tight enough to hold a considerable quantity of water. On some jobs holes had to be drilled from ceiling to drain roof slab. In one building water dripped from the ceiling after it had been waterproof for a period of five months, due to the collection of water on the slab in the cinder fill. In another case there was some dripping even after two years. This is a matter entirely beyond the control of the contractor, as it is solely a question of weather conditions, and can be avoided only in the engineer's design.

There is a question as to whether stairs shall be cast integrally with the floors or whether rods shall be left projecting from floor to bond in stairs, which are cast later. The latter method is much preferred by the writer.

Another important question which must be taken into consideration in the designing is whether a granolithic floor is put on as an integral part of the construction, or as a second operation, and if a second operation, what its thickness shall be. For economy's sake, both in materials and in labor, it is cheaper to put on the finish with the construction. Under these conditions, it is frequently impossible to keep off the floor long enough for it to harden sufficiently to prevent its being somewhat marred. If this is a serious objection, the finish must be put on as a second operation. As this does not bond sufficiently with the floor to be considered a unit, the construction should be thick enough to carry the load without any assistance from the finish.

If the finish be one inch thick, it is almost safe for the contractor to guarantee that it will be loose in spots, whereas if two inches thick it is pretty safe to guarantee it as solid and satisfactory. This adds to the dead weight and the expense. It is necessary to settle these points before construction begins in order to get the minimum of cost and the maximum of efficiency, as the amount of forms bought and the conduct of work are influenced by it.

Frequently, the location of construction joints between days' work is an item of importance, but these are almost never

indicated on plans, and must be discussed and settled. Some of the points which influence fixing their location are, the capacity of the mixing plant, sufficient supply of materials and the weather. Sometimes the latter causes several days' delay where continuous work is desired. There is a question as to whether the construction joint shall go in the middle of the span of a floor, or be made in line with the columns. The treatment in the two cases is somewhat different. If in line with the columns, these must be thoroughly reinforced above and below the floor, and steel plates used, otherwise they are certain to be split when the floor shrinks at the construction joint. If the building is to have contraction joints, the construction joints should be made so as to coincide with them.

The cleaning down and finishing the exterior of a building, according to the type of finish specified, whether it is left as it comes from the molds with just the bad places rubbed up, or whether it is to be tooled or plastered, will in some degree affect the design of forms, and, therefore, must be considered before work is begun.

The designing department of the writer's company has several times picked up defects in plans, such as hanging of large three-ply fire doors in an 8-in. brick wall, where the weight of the doors is greater than that of the brick work. The writer recommends that the iron door jambs be carried straight through from floor to ceiling and anchored to ceiling, in order that doors may stay where they belong.

It is somewhat common to put wall beams above the floor on account of letting in light at the ceiling line. Then the question arises whether the beams shall be cast with the floor or be cast separately. It is generally cheaper and of equally good construction to cast the wall beam as a separate operation, allowing the ends to rest in rebates in the columns and suspending the slab below by means of stirrups. Provision can be made for continuity by casting some holes in the columns above the floor at the proper points, through which the reinforcement for negative bending moments will pass, allowing the ends to extend well out in the adjacent panels. When properly grouted into place and panel cast this will be as strong as if cast as a monolith with the floor.

Because concrete is a plastic material cast in place, and because the molds can be made of any design, engineers seem to feel that there is no necessity for holding to any standard sizes for the members of a concrete structure, as they do when

designing in steel. An engineer can, however, use quite an amount of thought to good advantage in the selection of sizes, as the particular dimensions which best satisfy his designs will quite often not be the most economical. In one building of large size, in a single floor there were in the original design received 455 different sizes and styles of beams. The designing department of the writer's company found it possible, without impairing the result to be accomplished, to reduce these to less than a tenth of the original number, and by coöperation with the engineers finally succeeded in reducing the number to 52. *If the engineers realize that in the building of wooden forms for maximum economy these are made, from plans drawn to scale, at a bench on the ground and assembled in place without the use of any too' but a hammer, it will be seen that almost as great precision must be used in construction as with structural steel.*

The question of change of size of columns in every story, or once in two or three stories, is one of cost. The expense of changing the forms is usually greater than the cost of concrete saved on small columns where the reduction is less than three inches, and on large columns where the reduction is less than two inches. Therefore, it is not often economical to change the size every story. Often when the column is reduced it is desirable to use ahead the size of lowest story columns in order to avoid expense of splicing out beam and girder sides and bottoms. Sometimes when the upper floor has a lighter load than the lower, it would be possible to reduce the size of beams. Economy dictates that the depths may be reduced but not their width, because this would require splicing out all the floor panels and joists, which is more expensive than the saving in concrete.

Lastly, the question of whether the floor panels may be centered with wood or corrugated iron may be discussed, and must be settled very early. In the writer's opinion, the appearance of corrugated iron ceilings is better than that of lumber, and it is just as easy to attach inserts to the metal forms. They are somewhat more economical.

Uncommon Features, — In a certain mill, the basement floor was partly of beam construction with concrete slab and partly of concrete beams without slab, the floor being made of wood, as the owner desired opportunity for frequent changes of the arrangement of his mechanical plant. This caused special form work to be used, which could not be used again, and also made it difficult supporting the floor above.

The frequency of special features in a lower floor, and the certainty that the basement story height is less than that above, adds to the cost of form work. This is at a time in the process of construction when new lumber must be cut up although it could be advantageously used in long lengths on upper stories. If it cannot be used again, it has to be remade, and the remaking of second-hand lumber into new shapes is more expensive than when it is brand new.

Where extremely heavy loads are to be carried on columns, sometimes so much steel reinforcement is shown that it is impossible to use stone concrete, as the bars are so close together that the column really has to be filled with mortar. This is doubtless an oversight on the part of the drafting room of the designer, and makes a problem for the contractor to adjust before work can progress. Similarly, heavy girders have had such an amount of reinforcement that there was not enough concrete in the width of the girders shown to imbed the reinforcement, as shown on plans.

An unusual problem put up to the writer's company to solve in execution was a very high tower which had two floors near its top, one 160 ft. and the other 180 ft. from the ground, each of which carried a load of 400 tons on an area of 28 by 30 ft. This floor was supported on a central girder, running the short way, with beams running from it to the opposite walls. The requirement of engineer was that the walls and floors be cast as a monolith and be watertight as a tank, as moisture penetrating from driving storms would be a serious handicap to the operation of the plant. This unusual feature, high in the air, required absolute prevention of all cracks from any cause, impermeable concrete and as near continuous work as possible. Under ordinary conditions there would be frequent joints between days' work of reasonable size which might allow the peneration of the weather.

This problem was solved by a little lower working stresses in materials than is common, by a rich mixture carefully proportioned for maximum of density by designing forms for casting a large amount of concrete at one time, and by continuous work with different shifts of men, combined with very close supervision by more than the usual number of bosses, besides the inspector. The result proved satisfactory in every way.

Method of Drawing Details. — The preparation of drawings for details of steel and form work is very similar. They have been standardized as far as possible to simplify the work in the

drafting room, and also so that the men handling the plans outside can understand them easier.

Columns are shown full height from footing to roof, showing the outline which is to be built in forms, joints with curtain walls and floors, as they may occur, and the steel reinforcement shown by as simple a method as can be devised. Each beam is shown by itself inside elevation, and sections with notes as to the number and location.

It is seldom necessary to make an assembly, as the engineer's plans are sufficient for this purpose, but while the details of some engineers are sufficient, they are as a rule reduced to a system which experience has shown to be most useful to the men on the work. Three typical sheets of forms are shown to illustrate the method used.

Selection and Purchase of Materials.

The purchasing department is also quite busy, beginning before any work is done at site of building, and always keeping away ahead of construction requirements.

As stated above under the head of contract, the contractor is very largely a broker buying materials to be incorporated in a building. Some materials are easy to buy and some require a detailed knowledge of the materials themselves and also of the estimate and contract and the relation of one class of material to another. Therefore, there is a distinction made, classifying the simplest articles and duplicate orders as routine buying, another as experienced buying. Of the routine buying, some can best be done locally from the job and some from the main office of the company. There has been compiled a complete list of all materials which enter into a job, and then it is decided which of the routine items can most advantageously be bought by the main office and which by the job superintendent, and written instructions are prepared for these items. This table gives in the first column the list of materials, in the second the usual time which it takes to obtain these after placing the order, in the third column some explanatory notes giving necessary information, and in the fourth the time after contract is awarded at which information should be received in order to deliver completed building on time. This time assumes that the ordinary four-story mill building will be completed ready for delivery in four months from award of contract. On this list the great majority of items require information within one week, a few in two weeks, and the latest must not be delayed more than a

month from award of contract, if the probability of delay is to be avoided. It appears strange and engineers have been surprised when we have asked for full-size window details before the footings are in place, but when it is realized that from seven to ten weeks are necessary if the minimum price combined with quality is to be obtained, it will be seen that this request is not unreasonable.

In the purchase of manufactured articles such as doors and windows, and letting of subcontracts, hundreds of dollars can be saved and better results obtained if handled by a person who by long experience has become familiar with all the details of the materials themselves, the dealers and manufacturers in various localities and who is also familiar with the relationship of all these materials to one another, as well as with the estimate and contract. To illustrate one little point where a subdivision has caused expense. In order to save time, window frames have been bought by the job superintendent from a local mill. These are sometimes primed with paint by the manufacturer and sometimes are not. If the painting contract is let by another person without knowing what has been done with window frames, it has happened that priming has been paid for twice.

Similarly, all changes, either additions or deductions, from the original design, should be handled by one person in order to see that no mistakes are made.

The selection of aggregate for a job in a new locality is often considerable of a problem. Study is put upon it by all of those competent. A decision has to be made before the final design of mixing plant and its location can be determined upon because team and railroad deliveries will be at different places. The purchasing department never buys an unknown sand until it has been thoroughly investigated by a testing laboratory, although this may cause an annoying delay. The tests continue at intervals throughout the progress of a job. Once, gravel from the most available pit had a coating of a reddish substance appearing to the eye to be clay, which was strong enough to hold grains of sand to the stone even after it had been handled roughly with a shovel. By the usual eye and hand tests this material would have been rejected, yet samples sent to a cement testing laboratory showed on the average about 150 per cent. of the strength of the same cement with standard sand. It seemed peculiar that the fine red material should have no injurious effect on the tensile strength tests of briquettes with bank sand while low compression tests were obtained on curbs made with the gravel.

The laboratory testing the sand reported that under the microscope this fine red clayey material was really a very gritty substance, and called it finely pulverized rock. It clung tightly to the stone, binding to it particles of sand, and yet washed off when shaken in water. It appeared that if this fine material could be removed from the surface of the stone, and if it was not too plentiful, a perfectly satisfactory concrete would be obtained with this aggregate. Experiments keeping a batch in the mixer a longer time than is usually the custom appeared to clean the stone, and good hard concrete was obtained with a not objectionable pink tint. Extra mixing was done throughout the job with complete satisfaction.

The lumber and steel schedules are generally the first to demand attention. Lumber used in contact with cement is almost always ordered planed four sides. A correct ordering schedule for lumber cannot be made, of course, until the work of detailing forms is nearly completed in the drafting room. It is possible, however, to make an approximate schedule of same for canvassing for prices. By referring to standards we are generally able to tell in advance what sizes are wanted, and in this way be ready o order material forward immediately centering details are completed. As lumber arrives, the material of different dimensions, qualities and finishes is piled by a prearranged plan worked out in the office, handy to the woodworking shop, and given a number or letter obtained from key plan.

The steel is taken off the plans by one man and checked independently by another. This schedule is then studied in regard to reducing the variety of lengths, and frequently these can be reduced to one fifth of the number shown on plan. It is usual to order a schedule of bars three-quarter inch and larger in multiples of six inches, and to buy steel five-eighths inch and under in the longest lengths that can be put on a single flat car, and cut it up on the job. The largest size recommended in square is one and one-quarter inch, and one and three-eighths inch in round; the smallest, one-quarter inch, all sizes to be multiples of one-eighth inch. On one large job there were over 400 different lengths of bars shown on plans, and by scheduling large bars in multiples of six inches and ordering small bars in long lengths, as above described, the mill order was reduced to 46 different lengths. This method only increased the weight of order so as to cost eighteen dollars in excess of the exact schedule taken from plans. This amount was saved many times over in the

greater convenience of sorting and handling the steel. The manufacturers are required to deliver the small bars in bundles weighing from 125 to 145 lb. This insures the men's getting a load of proper weight for greatest efficiency. They are also easier to handle with no picking up of one bar at a time with the trouble of unraveling found with small sizes.

Management of Construction.

In the general management of the construction operations the writer's company has made radical changes from customary practice in the erection of reinforced concrete buildings. These changes have been made not from theoretical considerations and mere office studies, but for the sole purpose of reducing costs and at the same time improving the quality of the workmanship. As a result of the introduction of the methods described below, the labor cost of making, erecting and removing forms, which is one of the largest items of expense in a reinforced concrete job, has been reduced during the past four years over 30 per cent.

The general purpose of the new methods has been to plan out the construction details in advance so each skilled workman as well as each laborer will know just what to do, will work to the best advantage without the delays usually considered unavoidable, and will be assigned to work of a nature best suited to his ability. In this way he is enabled to go right ahead without the waits and the bother, equally vexatious to the workman and to the bosses, that are inevitable under the ordinary methods of management, no matter how well the work may be handled by the superintendent.

The task has been no small one and is not yet completed. It has involved, as essentials, thorough study of the plant layout, the establishment of standard methods of construction design and operation, the making of detail plans for forms, the routing of the men and materials, and the establishment of task and bonus arranged to give the workmen an appreciable increase in pay for speedy and accurate performance. It was recognized that Mr. Sanford E. Thompson had carried previous studies along these lines further than any one else, and he was, therefore, engaged in the first instance to coöperate with us in furnishing the basis for the systematic handling of the form drawings and the establishment of the routing and of the task and bonus.

The new methods have paid both from the standpoint of the contractor and of the owner, permitting smoother operation

of the work, and after making full allowance for increased overhead charges, materially reducing unit costs.

Drawings for Forms, Steel Bending and Plant.

In erecting a concrete building, one of the earliest and very important parts of the work to need attention is the form work.

A study of comparative costs on different buildings indicates that about thirty-five per cent. of the money spent is for labor, over one third of which is consumed in the making up, erection and stripping of forms.

This, combined with the fact that lumber and labor are continually advancing in price, would indicate that a very careful study devoted to reaching the greatest simplicity and regularity in making up panels, and of using the lumber with the most efficiency, is a vital factor in low cost work.

Forms. — In what follows, by panel is meant several boards cleated together so as to be handled as one piece. It is perhaps needless to state that in order to gain this efficiency, the study of the forms should not be left to carpenters, who are paid to drive nails, nor to the boss carpenter, who has his hands full overseeing the men under him, nor should the superintendent, with the burden of the whole building to carry, be given this problem; but it should be the sole work of a corps of men trained to think forms all the time, under the direction of a competent leader, whose experience in different types of buildings shall be considerable, and whose judgment is reliable. The principles

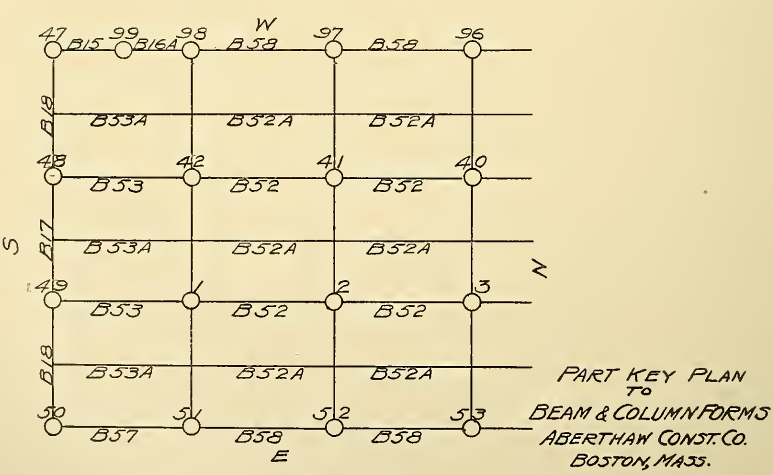


Fig. 2.

of design are standardized for beam floors, mushroom floors, columns and walls, and are never changed without a very valid reason.

In order for such a study to reach its greatest usefulness, it is absolutely necessary that the engineer furnish plans showing clearly, beams, columns, slabs, walls, etc., to the contractor before the job is started.

Having the complete plans in advance, it is possible to lay out the panels for columns, beams and slabs, not only in regard

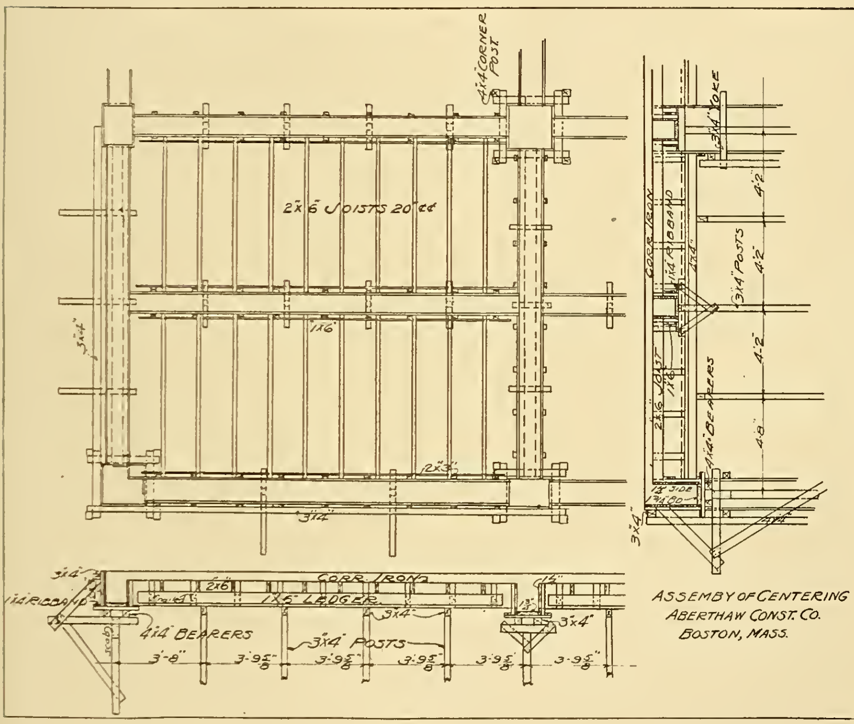


FIG. 3.

to the first use, but also to make provision for removing or adding strips where columns or beams are reduced or increased in width, for cutting off or piecing out where changes of length occur; in fact, to follow every panel from one position to another throughout its usefulness on a job.

Further, it is essential that this complete layout should be made enough in advance of the actual work to enable schedules of the lumber to be made from it, and leave time for a thorough can-

vass for prices before placing the order. Buying lumber by guess, necessitating cutting it up without relation to future use, is decidedly wasteful.

A form layout such as mentioned would consist of, first, key plans showing the location of each panel throughout the job; second, assembly plans showing the use and distribution of the lumber and the way all parts go together; and third, the actual panel details. Typical plans are shown in three illustrations, Fig. 2, 3, 4. Without complete plans of the building it is impossible to make the key plans or to lay out the panels.

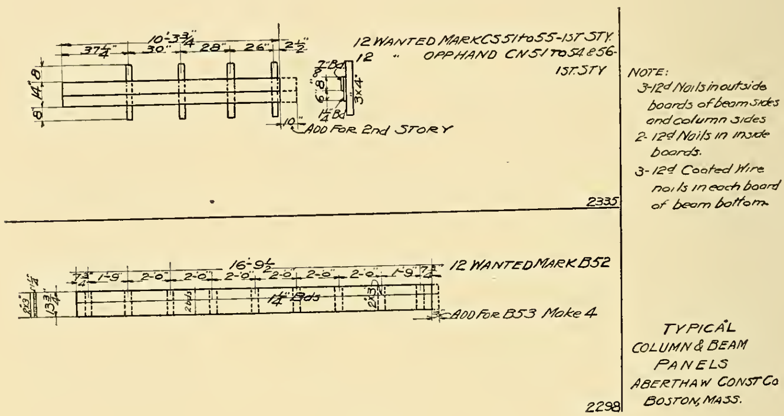


FIG. 4.

A standard method of drawing and marking key plans, assembly and panel details is used, so that the workmen, in changing from one job of the contractor to another, may find everything as they have been accustomed to it. On the sheets nothing should be left to the outside men to add, but every detail, size of boards, number location, and size of nails, clearances, cleanouts, etc., should be indicated or called for. The kind and dimension of lumber in one city differ from that in another. The design must be in accordance with the market.

The question next arises, "What is the cost to the contractor of such layouts?"

So many variables enter into this that it is impossible at the present time to give any actual standard. It is obvious that, in a job that is simple and regular, of several stories in height, with columns and beams that do not vary in size in the different stories, there will be fewer panels to lay out, as each panel will apply in a larger number of places.

Actually, on a large regular job this cost is very low, almost insignificant, while on a small job, especially if irregular, with small panels and frequent changes, it may be relatively quite large. On a mushroom job the cost is usually less than on a beam job, as practically all the panels are confined to columns and wall beams, if corrugated iron is used in forming the slabs.

A careful study of the spacing of posts, girts and joists of various dimensions, to carry the varying dead loads of concrete, has been made, and tables prepared based on the net section of dressed lumber, so that designing is reduced to looking up dimensions in tables and laying out results. Thus hereafter the drafting room cost can be somewhat reduced.

On a typical mill building having lower floor of beam and girder construction, the others being mushroom, there were 179 000 sq. ft. of area in contact with forms. Forty-two drawings were made, detailing 326 different kinds of panels. The number of panels scheduled to make up was 996. This gave an average of three panels of a kind. The maximum number of repetitions of a single panel was forty-eight; the minimum number was one. The cost of detailing forms amounted to thirteen cents per hundred square feet of contact area. If this building had been mushroom throughout, instead of being partly beam and partly mushroom, the number of panels would have been reduced and the corresponding cost lower.

It may be stated, in passing, that the expenditure of this money is amply justified by the reduction in the total cost of form work.

So far, in showing the importance of getting complete structural plans very early in the job, but one portion of the subject has been touched.

Frequently the decision as to what type of window is to be used is delayed. In concrete work a different kind of rebate is formed for each varying form of window. With rolled metal sash a strip rebate is left in the column and wall beam bottom, while for wooden frames a rebate from one to four inches deep, depending on whether plank or double hung box frames are used, must be left extending from near the outside face of column or beam to the inside face.

These details must be in the hands of the contractor before the erection of forms is started, and preferably with the other details. All inserts, anchors, wall ties, etc., should be shown in time to enable them to be ordered and attached to the forms without delaying the work. Piping and plumbing must be de-

signed so that sleeves coring holes may be left for their passage. Electric wiring must be arranged for, so that conduits may be laid on the forms before concreting. In fact, plans on a concrete building cannot be too complete, or furnished too early.

Frequently a contractor desires to change certain details on a building, believing that some other method may give the same results more cheaply. The nature of these was mentioned above, under the heading of "*Design—Minor Features*." Many of these questions are worthy of considerable discussion, and, undoubtedly, different opinions might be formed, — depending on the methods of the particular contractor or on local conditions.

Steel Bending. — A sketch is made for every shape and size of bar that is bent on the job, the number, size and location of each style of bend are tabulated, and these data are furnished the steel foreman.

Drawings for Plant. — The general arrangement, amount and kind of plant are determined for any given job by the writer, general superintendent and job superintendent. These data are turned into the drafting room and laid out to scale. The drafting room has standard plans giving the principal dimensions and all necessary information concerning the use of each big tool such as mixers, elevators, engines, woodworking machinery, temporary buildings, and any other information that is necessary to enable a draftsman without any special knowledge of design to combine the data given him in free-hand sketch form into working drawings for the use of the men on the job.

Plant.

The study of the amount and location of mechanical plant has to be made immediately after the contract is awarded if work is to be started promptly, as part of it is put into operation with the very beginning of construction. As a good deal depends upon the amount, design and promptness of delivery, so far as economical construction goes, the best thought of the whole organization is put on the subject. For instance, one of the younger men made a study for a large job on basis of a story a week. To obtain this rate one mixer and two stories of forms more were required than if the progress was slowed down to a story in nine working days. Such speed was not demanded. A conference of all hands corrected the first study, making an estimated saving in job cost of about $10 000.

Before the location of concrete mixing plant can be decided upon, the source of supply for aggregate and cement must

be settled, which in turn settles the method of delivery. If materials are delivered by teams, the mixing plant will usually have to be on the front of the building for the economical handling of aggregates; if by rail, on the rear of the building. The size of the mixing plant is determined by the amount of concrete to be mixed for the entire job, the time allowed by contract to complete mixing, and the maximum quantity that has to be placed in a single day. Usually this can be done by one mixer taking as a charge a barrel of cement and aggregates in any proportion. A common arrangement for the concrete mixing plant is to lay an industrial railway track so that aggregates are unloaded by shoveling from steam railroads into industrial cars which dump directly into a super-hopper, set flush with the ground, over the mixer. A pit is dug outside the building sufficiently deep to take the super-hopper, feeding the mixer by gravity, and the mixer in turn dumps by gravity into an elevator bucket that runs vertically through a steel tower just outside the wall, so that it discharges through a chute into the building. This, as well as all other tools, when possible, is driven by electric power. The pit acts as a sump well to drain the surrounding ground and has to be pumped out.

The method of distribution of concrete through the building requires some consideration. If a building is compact and large masses are placed within a limited area, spouting is desirable. If the building is spread out and quite small quantities of concrete used, two-wheeled push carts are used, while if large quantities are required over quite an area, industrial tracks laid on horses so as to elevate them about 18 in. above the forms are run over the latter to distribute concrete a batch at a time. The amount of track, the number of curves and switches, number of cars and all the minor items down to the last bolt must be carefully determined at the very outset in order to save delay in erection and several shipments in less than carload lots.

If it is decided to set up a woodworking mill, the kind and amount of machinery necessary must be carefully determined according to local conditions. If, in the shop, only bench and cut-off saws are used, on the standard sketches on file in the drafting room all the rest of the information can be found to make it a complete plant. If, in addition, a planer, boring machine and emery wheel are wanted, it is only necessary to look up other standard drawings to get the correct size of shop and the arrangement of tools, shafting, motor, benches, etc., which previous experience has dictated to be necessary for best results. The

wrong location of mill and the wrong machinery sometimes cost more than the possible saving by the use of power tools over hand work, and these questions must be carefully considered and settled at a very early stage.

The question of temporary buildings often is serious. The size and location for temporary office is a simple matter, but for cement, tools and equipment more thought is needed. Sometimes a cement mill is so regular in its shipments and the railway service so sure that a small supply only need be carried on hand for emergencies. On other occasions it may be necessary to store sometimes twenty carloads. It is not easy to determine these factors, which are beyond our control, without the actual experience, but unless a fairly close approximation to the actual facts is worked out there is likely to be extra cost from too big a building unused, or too small a one to receive the materials to be cared for, which increases the demurrage account.

There are standard lists of small tools compiled for quick use for jobs of various sizes and characters, so that it is merely necessary to call for schedule one, six or whatever it may be, to start work.

The method and equipment for handling excavation must be settled at the earliest stage in the discussion of plant.

Staging. — A frequent cause of injury to workmen is the breaking of stagings on which they are at work, and the writer believes that this is due to leaving the design and execution to the workmen themselves. Although there may be a large quantity of excellent material ready at hand, it is not uncommon for workmen to pick out inferior stock for building a stage. To avoid these difficulties, the principle has been adopted of designing all stagings in the office for any important work, as for the outside of a building. The stage is laid out, giving dimensions and spacing of lumber, the sizes, number and location of nails, whether the stage be built from the ground up, whether it be a cantilever from an upper story window, or a swing stage hung by ropes from the roof. The plan states the maximum safe load which the stage is permitted to carry. Material is selected for the workmen, and before any are allowed to use it, its construction is inspected either by the superintendent or by his authorized representative. In this way as much safety is insured the men as the nature of the undertakings will permit. The men work with assurance of safety and therefore ultimate economy results.

Organization of Job Force.

After the job superintendent is determined upon, he is taken into consultation for every other step which follows. The selection of all his subordinates is made in coöperation with him,—assistant superintendent, clerical force, carpenter, labor, concrete, steel and other bosses; the principal mechanics and even the leading laborers are all selected in advance from among those working on other jobs. The superintendent, where possible, is given at least a week to study plans and specifications in coöperation with his principal assistants and the office force, before anybody appears at the site of the work except for the mere purpose of studying local conditions. By this time a well-defined plan has been worked out as to the sequence of various operations, the kind and amount of mechanical plant, and its location; schedules of the materials first needed have been made and orders placed, so that by the time actual operations begin in the field the plans are so matured that there are few false moves. The peak of the superintendent's load is the first few weeks during the organization and starting the work. During this period he should have his full executive force, although each subordinate may not at that time be doing nearly as much as he will be called upon to do later.

Planning, Routing and Cost Accounting.

During the early stage of actual construction, the superintendent makes a careful study of the handling of the work from the beginning to the very end, making a detailed schedule of work along the general lines which had been previously determined in the office.

The job office work is in charge of a chief clerk, who in addition to overseeing the work of the material clerk and timekeeper, has also charge of the cost-keeping. The timekeeping methods were described fully in a paper by the writer entitled, "Cost of Concrete Construction as Applied to Buildings," published in the Proceedings of the National Association of Cement Users, Vol. 5, 1909, page 38; and that method is carried out on all jobs at present.

The chief clerk figures from the time sheets the cost, and two records are kept of these; one for the superintendent's use in card index form, and covering every single item on the job. The other considers only the large items, such as concreting floors and columns, placing reinforcing steel and form work for floors, columns, beams, etc. The latter costs are recorded on

cross-section paper. These diagrams are posted where the man who has full charge of each item can consult same when convenient for him.

The foremen take a particular interest in these, as it is natural to suppose they would. Figures meaning a little larger or smaller cost convey some idea to them, of course, but a line traveling upward or downward and above or below a red line which is recorded as the desired cost line, the foremen grasp the meaning of very easily. Keeping the foremen keenly awake to the cost of the work they are doing has not been, so far as can be seen, detrimental to their turning out good work. It should always be accompanied, however, by more rigid inspection in the first instant, and explained so that they may definitely understand that any lowering of cost shall be considered detrimental to their interest, unless the quality remains equal to the standard.

The execution of a job is divided into two departments, — the planning and routing, and the operating, the former being in charge of a man conversant enough with our standard methods to plan carefully the different steps of the work and say what to do, while the latter is placed in charge of a practical man of experience, whose duty it is to tell how the work should be performed. Work carried on in this way requires the men to receive orders from two foremen. There is however very little trouble encountered by reason of this, as the routing foreman remains in a field office and gives instructions wholly on written slips, and instructs only as to what shall be done. The operating foreman has direct charge of the handling of the labor gangs to make sure that what is being done is done in the proper manner, both as regards safety, appearance and economy.

The moving boss and his gang are a very important factor in the success of routing. He must be a painstaking, tireless fellow, who is always on the move and must have sufficient intelligence to see that the men under his charge have done exactly as told, taking the correct materials, carrying them to the proper place and laying them right end to and right side up, as per the written instructions from the routing foreman. The men under his direction must be active, strong and energetic, — the pick of the laborers, because they have a great deal of moving about and are in small groups or alone; therefore they are not under the close eye of their foreman. They must be men who will work without being too closely watched. This man receives instruction as to how each laborer will do his work from the operating foreman.

It is necessary for the routing department to be fully posted at all times as to just what is being done in regard to delivery of material needed and completion of tasks as specified. This is taken care of by a daily conference between the job superintendent, operating and routing foremen. In fact, the success of this system depends very much on a complete coöperation between the operating and the routing foremen.

The operating foreman, by mingling with the workmen at all times, is able to give considerable information to the routing foreman for his use in future planning. He has no authority to give instructions regarding what shall be done to any of the sub-foremen on the job, but makes all suggestions to the routing foreman.

The form work, in the older method of management, was the most difficult to organize and systematize with any efficiency, and, therefore, the first attention was given it under the system of planning and routing. It was found that this class of work was very easy to systematize and with much effectiveness, more so than the handling of concrete or of steel reinforcement, although these, to a less degree, have been brought into the system. The application of this method to form work is as follows:

From the piles made, when first received from the dealer, the moving boss moves the lumber to the sawmill in accordance with written instructions. The mill-man is told by his instruction slip just what length to cut these pieces to and what ripping is to be done on each board or stick, if any. After this is done the moving boss moves same to the different making-up benches, still in accordance with written slip to that effect.

The work is planned out with considerable care quite a way ahead so that each making-up bench has at all times the proper amount and kind of boards, cleats, nails, etc., which will be required to make up the panels that each pair of carpenters is told to do by the instruction slip and accompanying drawings. As soon as these panels are made they are marked by proper panel numbers taken from key plan, and the moving boss removes them to a stock pile where they are stacked by a pre-arranged method, and from which they are taken as needed during erection.

This method of making up forms has been followed for a number of years with considerable success and improvement over all other methods. Considerable saving has not only been made in the unit price of making up of forms, but a large saving in the

use of lumber has also been effected. Under this system the carpenter foreman is relieved of the work of laying out each change of panel, as well as for laying out the panel details themselves, and, instead of spending a lot of time working on plans, while his men soldier, can give his entire attention to the method of making up the panels and to their erection in building. It is along these lines he has been particularly trained by experience, and he is able to give the carpenters the benefit of this, more fully than he could in any other way.

The high price carpenters are also given an opportunity to devote all their time to actual carpenter work. They do not have to bother with looking up stock which they will require for the panels they are making or erecting, the material being always piled right behind them ready for their immediate use.

The method of task and bonus pay is frequently followed on work, and by means of data previously obtained it is possible to ascertain very accurately what the correct best time should be for the making up of any particular panels by a pair of good carpenters. For doing the work in this tasked time an increase over their usual hourly wage is paid of from 25 to 30 per cent. On the erection of the forms a similar method is followed. All material is moved from the stock piles to the point of erection by common laborers, under the leadership of an efficient moving foreman. The foreman receives all instructions on a written slip. The planning department is able at all times to make sure by so doing that the carpenters have the material they want, when they want it, and where it will be most convenient for their use. No carpenters are allowed to carry lumber, but are restricted to really doing carpenter work.

On the erection of the posts, girts and joists, to support the floor panel forms, instead of erecting each post separately and then putting the girts on top of these, they are assembled as frames in a horizontal position and erected in large units, much in the same way that a frame house is erected. The work is done by one carpenter with the help of three good laborers.

The work which the steel and concrete gangs do is planned by the routing department, but not in quite so much detail as is the case with the form work. The steel foreman bends the bars in accordance with data copied from the office schedule on to a card. These are made out in the office by a clerk, directly from the plans. After bending, the foreman tags the bars properly, stacks them as per plan, and card is returned with the time to do this work noted thereon. These cards give data

under many different conditions, which enables the superintendent to figure time for task and bonus work.

The saving which is effected in the concrete work is due to the fact that this planning of the whole job gives in advance fairly accurate information as to just what will be required of this concrete gang each day, and by canvassing the whole job for miscellaneous work, which this gang can do, when not concreting, the efficiency of same is increased quite materially.

From a study of what precedes, it will be seen that, if every class of labor obeys orders and there is an ample supply of materials, with no lack of information as to requirements for future work, there can be gotten a smooth running, clocklike system resulting in greater economy than can be obtained under any other method. This system requires about one boss to not over six or eight men, yet enough work can be obtained from these to more than make up the unproductiveness of the bosses not working with their hands.

A slip in any action, or lack of information from the engineers, non-receipt of materials, or trouble with the labor, is as disastrous to the successful operation of the system as the fumbling by the runner of a forward pass from the quarterback in football. The coöperation of the engineer is, therefore, most earnestly desired to give full information long in advance of its actual use, in order to prevent any break in the smooth operation of the system.

In spite of the wages of carpenters nearly doubling in twenty years, while the quality and intelligence of those who do the work is less; because house and finish carpenters will not do this kind of work as formerly, and in spite also of the great advance in price of lumber, combined with a falling off in quality, the unit costs obtained by the above system are materially lower than when job superintendent was left to himself. The total gain in efficiency is about fourfold.

Weather Conditions Met with in Construction.

Protection of Work from Rain. — It is unnecessary to protect form work from the rain, as usually it is only possible to get green lumber, its tendency being to shrink out of shape rather than swell. Rough concrete never need be protected from the rain before setting, only from the concentrated run-off over some portion of the work which might wash deeply the cement out of a small area.

A troweled finish, however, must be protected against being

pitted by the rain or damaged by concentrated streams. This is usually done by tarpaulin, which consists of 12-oz. cotton duck rendered waterproof by being saturated with " Preservo " after being made into covers 20 ft. square. These are supported by a temporary frame. They are somewhat of an inconvenience to the finishers, and decrease the amount of work which they can do.

If rain is expected, it is usual to delay work until after the storm is over, if possible; otherwise, to build a shelter. Sudden showers require quick decision whether there is time to build a shelter, and also its cost, as compared to making repairs on the surface if left exposed. As a rule the shelter is built.

Protection from Sun. — If there is to be an unavoidable delay in placing concrete after forms are erected, it is best to protect them from the sun if possible, because they shrink so as to open up cracks which permit the mortar to escape, leaving a bad surface on the concrete. Rough concrete does not require any protection from the sun, with rare exceptions. It is usual to cover up a granolithic finish for at least five days. The materials most available and most economically used for this purpose are rough bags, such as come around bales of cotton, or wool, shavings, sawdust, and sand. The object of these is to retain the water which is put upon the surface to keep it wet and to maintain it at a fairly uniform lower temperature than direct sun action permits while setting.

The writer considers it unwise to spray bare concrete in the hot sun, and the use of roofing paper is but little better, because it retains moisture but a very short time. The water falling on a surface heated directly by the sun chills it suddenly, causing it to shrink, and may cause the very cracks which one is trying to avoid.

Protection from Frost. — The aggregates must be free from frost when mixed. A live steam pipe can be shoved into the sand pile, the escaping steam heating it and removing all frost. The same may be done with the stone, but a canvas should be thrown over the top of the pile to retain the heat, which more readily escapes. Where a considerable amount of heating is provided for in advance, steam pipes are laid on the ground, and stone as received is dumped upon them. Then there is a canvas thrown over to prevent storms getting into the pile, and to retain heat. The frost is thus easily and economically removed.

Salt is frequently used in the water to lower its freezing

point. It is seldom worth while to heat the water itself. Little care need be used to prevent mass concrete from freezing, as the frost will usually only strike to a depth of about one inch. Buildings are inclosed with tarpaulin tied on to an outside staging, and the enclosed space is heated with salamanders burning coke. Sometimes it is possible to use steam.

Frost is removed from form work by the use of salt and steam, and if the concrete surface is left rough it is common to sprinkle the top surface with salt to prevent freezing. In winter it is very common to put the finish on as a separate operation, after building is enclosed, and not as an integral part of the construction, on account of the danger of freezing. When it is put on, it must be kept from freezing for the first forty-eight hours.

The expense of protection against the weather is not very great, and good results can be so surely guaranteed that it is not usual for the writer ever to discontinue work on account of cold weather.

Occasionally it is necessary to make some provision for the protection of the men. Shelters or wind-shields are built in front of the benches where carpenters are making up forms, as well as around the men at the concrete mixer, whose work does not necessarily keep them warm. Where excavation is going on in the open it is expedient to have a building with a good fire where the men can warm themselves when necessary; and on a few jobs it has proved to be wise to furnish hot coffee free in these shelters.

DISCUSSION

Mr. Sanford E. Thompson (*by letter*). — This paper of Mr. Wason is of great interest to contractors and to engineers associated with construction both in the discussion of problems successfully handled by a contractor in reinforced concrete and especially in the detailed descriptions of the methods of managing the work.

His statement regarding the reduction in cost due to the systematic planning and routing of the construction shows clearly the money value of systematizing all operations and detailing them so that the labor of the men on the job may be made effective and loss of time largely eliminated.

One point brought out in the paper is the necessity for thorough coöperation between the management and the men in the field. At the start the management fully appreciated the re-

ductions in cost that must accrue, while at the same time they were aware that the changes would require the exercise of not a little grit and backbone until the new methods became thoroughly routine. The superintendents and foremen were led to take a new viewpoint and to appreciate the fact that reductions in labor cost lay not in standing over each gang of men with a club, but in so planning the work in advance that the men would accomplish their work easier and to better advantage and by the best methods.

In the organization described, it is noticeable that there are two distinct foremen over the same body of men. This is quite contrary to the older methods of management, but is merely following out the functional idea in the Taylor methods. It has been found by actual experience that just as in the schoolroom a separate instructor may be employed for each branch, — one for sewing, another for gymnastics, and another for the teaching of the three R's, — so in industrial work, by giving separate functions to different foremen, it is possible not only to plan out the work to better advantage, but with the combined efforts to more nearly approximate the ideal superintendent referred to in the early part of Mr. Wason's paper.

The overhead charges by the new methods are increased, since these so-called office men are really doing work which is usually being done in the field, but they are doing it to better advantage and more cheaply. For example, when instructions are given to the carpenters for making up the various kinds of forms, it is necessary for someone — usually the superintendent or carpenter foreman — to decide on the design to use for each special case, to figure from the plans the dimensions of the forms, and finally to lay the work out on the bench and tell each carpenter just how to do the work. In the plan described by Mr. Wason a part of this work is done more accurately, at less cost and to better advantage, in the office, by men who are trained to it, who have for reference standard designs, and who have a comprehensive view of the whole situation. They can thus save an immense amount of material by arranging the different parts so that the lumber and other materials will work out to the best advantage. The saving attained by substituting laborers for carpenters to handle all the rough material and the advantages of planning out the work for each man so as to avoid waste of time is obvious.

It must be remembered — and this is a point often lost sight of — that a 25 per cent. or 50 per cent. increase in the amount

of work accomplished by a gang of skilled and unskilled workmen through improved methods and added interest will pay for extra office work and leave a large balance to go toward the reduction in net cost of the job.

Actual records of costs of forms on various jobs handled by methods similar to those described, have shown a saving of 25 per cent. to 50 per cent. over identical work done by ordinary methods, even when all overhead charges are taken into account. In the making of forms for a factory of ordinary type, with the usual variation in the sizes of members, it has been found possible to bring the cost down to $1\frac{1}{4}$ cents per square foot of surface of forms actually made, this price including cost of drawing form plans, wages of foremen, and all other job expenses.

Similar methods to those desciibed by Mr. Wason have been found equally applicable to other classes of construction work. In such operations as trenching and pipe laying, for example, the methods have resulted in large reductions in cost. In a job like backfilling, for instance, which is so frequently a place for soldiering, very large reductions in cost are possible.

In the building of houses, especially where several houses are being built at the same time, planning, routing, and even task and bonus, are in successful operation. In one case, for example, a large group of houses now in process of erecting is being handled in this way, — houses valued at $6 000 to $12 000 each, — with no two at all similar in design. The work is going smoothly, cost is reduced, and the quality of the work is greatly improved over that which can be done by subcontracts.

In considering the introduction of the new methods, the company who undertakes it must appreciate that they do not consist simply in the taking of stop-watch observations for the purpose of speeding up the men, but to be successful, must embrace a thorough study of all divisions, and the introduction of sufficient system, of a kind which has proved successful in practice, to properly develop and carry out the plans which have been laid out in advance.

[Note. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1913, for publication in a subsequent number of the Journal.]

THE WORK OF THE DIRECTORS OF THE PORT OF BOSTON.

By John L. Howard, Member of the Boston Society of Civil Engineers.

[Read before the Society, October 15, 1913.]

Under the provisions of Chapter 748 of the Acts of the year 1911, relative to the development of the port of Boston, and approved July 28, 1911, it was provided among other things,

"that the Directors of the Port of Boston shall be the administrative officers of the port, shall cause to be made all necessary plans for the comprehensive development of the harbor, shall have immediate charge of the lands now or hereafter owned by the Commonwealth upon or adjacent to the harbor front, the construction of piers and other public works therein, shall administer all terminal facilities which are under their control, shall keep themselves thoroughly informed as to the present and probable future requirements of steamships and shipping, and as to the best means which can be provided at the port of Boston for the accommodation of steamships, railroads, warehouses and industrial establishments."

They were also given the right to take and hold property, to equip piers, and were given the power to lease property for twenty years, but no lease for more than five years is valid without the approval of the governor and council.

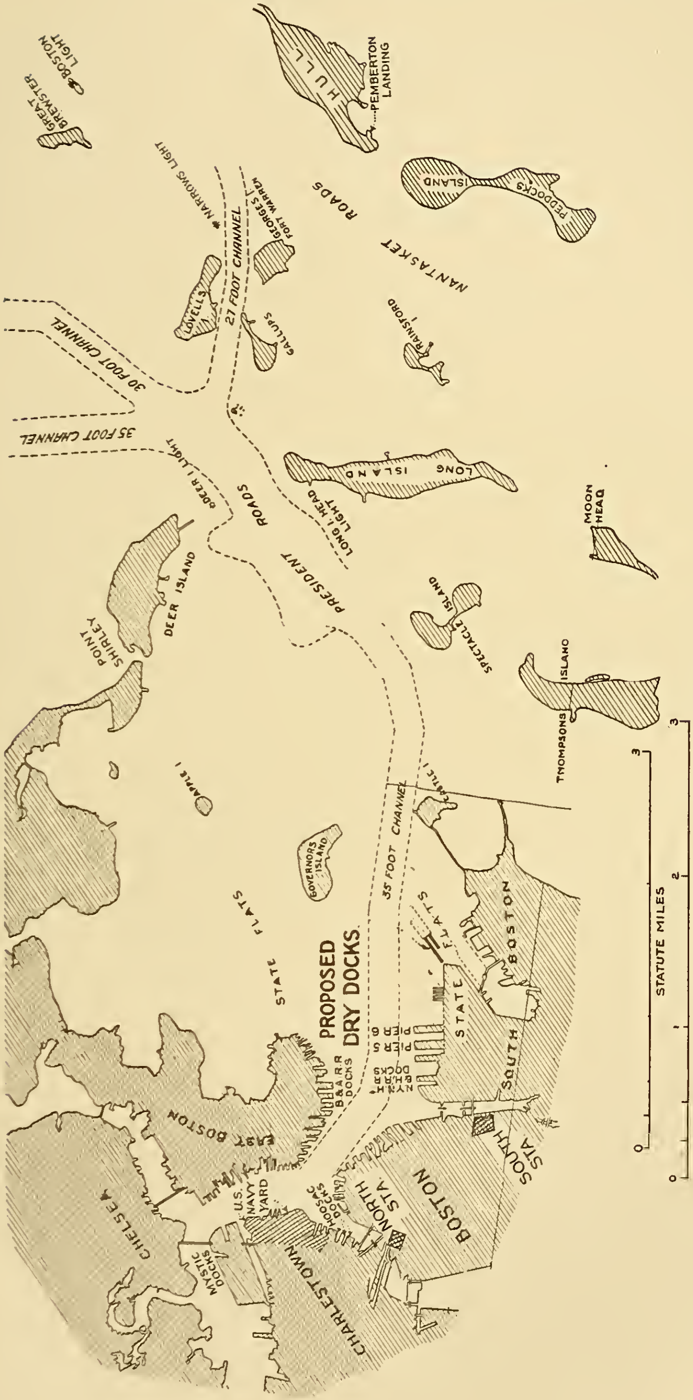
The limit of their jurisdiction in Boston harbor extends westerly from a line between Point Allerton on the south and the southerly end of Point Shirley on the north.

The members of the Board were first appointed December 6, 1911, and there has been, therefore, less than two years in which certain results have been accomplished and certain policies adopted.

Boston Harbor.

The harbor itself is most advantageously situated, being well sheltered from storms by numerous islands and requiring only an hour's sail from Boston Light to the piers. This is far better than in New York, which is two hours' sail from Sandy Hook; or Baltimore, at the head of Chesapeake Bay; or Philadelphia, a long distance up the Delaware River; or Montreal, one thousand miles up the St. Lawrence.

The main ship channel has a minimum width of 1 200 ft., with 35 ft. depth of water at mean low water, or $44\frac{1}{2}$ ft. at mean



BOSTON HARBOR.

high water, and the national government has now provided funds for a survey to determine the cost of making a channel with 40 ft. depth at mean low water.

Boston is the nearest of the north Atlantic ports to the ports of Europe, the distance to Liverpool being only 2 862 miles, while Montreal is 2 972 miles, New York 3 056 miles, Philadelphia 3 199 miles and Baltimore 3 355 miles. In other words, for the same operating expenses, the steamship companies could make 15 trips to Boston, while making 14 trips to New York, or 13½ trips to Philadelphia, or 12½ trips to Baltimore.

Boston's Commerce.

In the last ten years Boston's imports have doubled, while in the same time her exports have decreased 50 per cent., as shown by the following figures:

	Imports.	Exports.
1901	$61 452 370	$143 708 232
1911	129 293 016	69 692 171

Boston's standing among the ports of the world as given by the figures for 1911 is shown by the following table:

	Total Entrances. Net Tons.
London	19 663 000
Liverpool	14 613 000
New York	13 674 000*
Antwerp	13 349 000*
Hamburg	13 176 000
Boston	11 843 000
Rotterdam	11 052 000*
Hongkong	10 467 000*

Existing Conditions.

Prior to 1912, not a single pier or a single foot of the water-front in Boston harbor that was owned by public authority was in use for commercial purposes. The ownership rested entirely with private parties and chiefly with the railroad corporations. Such conditions, of course, were not conducive to the best interests of the port. Each railroad was interested only in traffic originating on or passing over its own lines or being shipped from its own piers.

* Not including coasting trade, figures for which are not kept.

There was no easy way to transfer freight from one railroad terminal to another, and the charge for this work was such as to discourage rather than develop traffic.

Perhaps the first step in the new development of the harbor may be said to have occurred eighteen years ago when in 1895 the legislature of that year, under Chapter 291, provided for an "investigation of the wants of the port of Boston for an improved system of docks and wharves, and terminal facilities in connection therewith," and a commission consisting of Woodward Emery, J. R. Leeson and Clinton White made a very comprehensive report on the subject in January, 1897, and it was, probably, largely as a result of their report that Commonwealth Pier was built by the Harbor and Land Commissioners between 1898 and 1900. The pier consisted of an earth-filled central portion, 1 150 ft. long by 300 ft. wide, within rubble masonry retaining walls surrounded on both sides and one end by a plank platform 50 ft. in width supported on piles, making the outside dimensions 1 200 ft. long by 400 ft. wide. The platform was supported by oak piles 6 ft. apart, in bents spaced 8 ft. on centers. The berthing space on both sides and one end was dredged to a depth of 30 ft. at mean low water. The cost of this pier was about $400 000.

Commonwealth Pier No. 5.

This pier stood idle for ten years and was pointed out by many people as an object lesson that while the state might construct piers there was no business for them after their completion, and that it was, therefore, very unwise as well as unprofitable to spend the public money for such purposes if no better results than this could be shown.

In the fall of 1910 this pier, together with another parcel of land on the opposite side of Northern Avenue, was leased to the Old Colony Railroad and its lessee, the New York, New Haven & Hartford Railroad, for $70 000, this being the first return received by the Commonwealth on its investment.

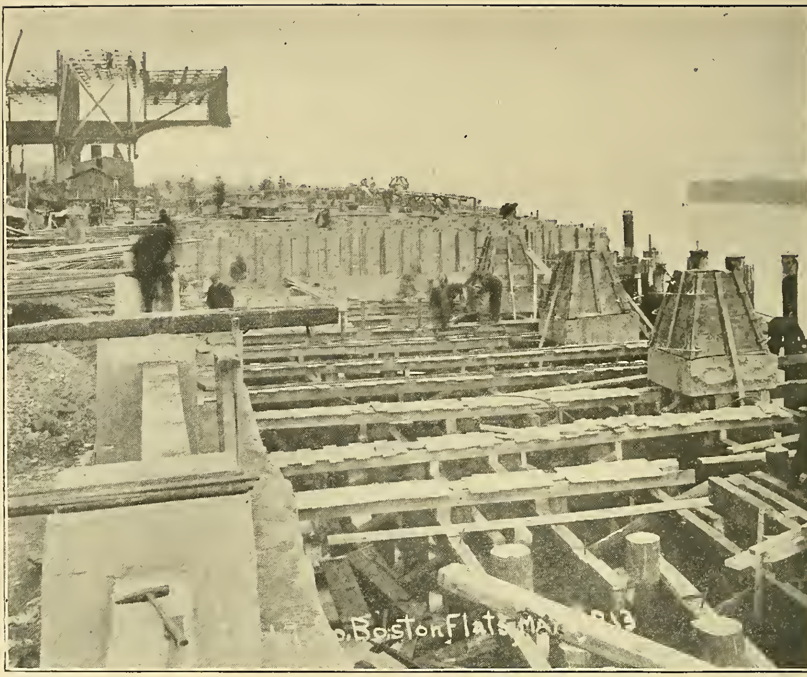
After the appointment of the Directors of the Port of Boston it soon became apparent that if the commerce of the port was to be developed, it was absolutely necessary that a steamship and railroad terminal under public ownership with all modern facilities for handling cargo and freight must be established. With this object in view, the lease to the Old Colony Railroad was canceled with the approval of the governor and council on November 6, 1912, and the Commonwealth was thus re-invested with

the ownership of the pier and adjacent land. At the time of the abrogation of this lease it was further agreed between the New Haven and Boston & Maine Railroad that as far as legally possible they would

"make the Boston rates apply to and from said Commonwealth Pier and other piers whether now or hereafter constructed, which are now or may be hereafter owned or controlled by the Commonwealth in South Boston, and shall make no charge additional to the Boston rate to be paid by the shippers or receivers of freight at the South Boston piers or the adjoining docks. It is the intention of this provision that all business over the New Haven to and from the South Boston piers which are accessible to the New Haven by rail shall be at the flat Boston rate, and that as to business to and from the South Boston piers over the Boston & Maine, the latter and its connections shall absorb the cost of transfer between said piers and Boston & Maine points out of the operating expenses of the Boston & Maine or out of the through rate as the case may be, so that no charge additional to the Boston rate shall apply."

Following this, an agreement was made on the twenty-first day of November, 1912, with the Hamburg-American Line. Under this agreement the Hamburg-American Line agreed "to operate a steamship service between Boston and Hamburg beginning in May, 1913," with the steamships *Cincinnati* and *Cleveland*, to continue till November 13, 1913, or thereabouts, the service to be resumed in 1914 with the addition of the steamship *Amerika* or other large passenger steamships, to be followed in 1915 with the steamship *Kaiserin Auguste Victoria*. The Hamburg Line is to be furnished free wharfage by the directors at the Commonwealth Pier, but the Hamburg Line agrees to pay the directors 6¼ cents per passenger for the use of passenger accommodations, but such charge shall not amount to less than $2 500 or more than $5 000 in any one year.

The pier and sheds furnished under this agreement "are to be of modern fireproof construction . . . with the necessary slides for cargo from the upper decks and elevators for lifting cargoes to and from the first floor. The sheds, three in number, are to be double deckers; the upper deck of the central shed, to be devoted to passenger traffic only, to have sufficient space reserved for the proper accommodation of all classes of incoming and outgoing passengers. The two outside sheds, both upper and lower decks, and the lower deck of the center shed, are to be devoted exclusively to freight traffic."



Commonwealth Pier No. 5. Rebuilding Timber Platform.

Commonwealth Pier No. 5. Completed May 31, 1913.

One outside shed and the lower story of the center shed, with car trackage on the pier with necessary railroad connections and satisfactory street approaches, were to be completed by May 1, 1913.

Upon the signing of this agreement the engineering department was directed to prepare plans and specifications for the construction of the sheds, the rebuilding in a fireproof manner of the timber platform outside the filled portion of the pier, and the necessary street and railroad connections. The plans and specifications were ready in one week's time and bids were received in another week, on December 6, 1912, and the contract was signed on December 9, 1912. The contract was awarded to H. P. Converse & Co. and amounted to $1 017 258.70. It provided that extra work under the contract should be done at cost plus 7½ per cent.

Pile and Timber Platform Rebuilt as Fireproof Structure.

The wooden decking and stringers were removed. All broken and decayed piles were replaced by new oak piles. The piles were cut down in most places to elevation 14.0 and a reinforced concrete beam 12 in. wide and 4 ft. deep was built on top of the piles and anchored to the piles by U-bolts. On one portion of the platform where a fire had partly destroyed the platform and the tops of the piles, the piles were cut off at a lower elevation, at about mean high water, and cast-iron spools were spiked to the tops of the piles and embedded in the concrete beams, which at this point were about 8 ft. deep. Economy holes 4 ft. wide were cast in these beams to reduce the amount of concrete. An additional row of two oak piles was driven between the old bents to assist in taking the load from a railroad track laid near the edge of the pier. On top of these concrete beams was built a reinforced concrete slab 7 in. thick, which forms a continuation of the lower floor of the shed. Clusters of 9 piles each were also driven 20 ft. on centers to support a line of columns for the outside wall of the shed. All piles driven in water under the platform are of oak, 50 to 65 ft. long and penetrate not less than 15 ft. into the clay bottom. Some difficulty was anticipated in driving the piles through the riprapped slope under the platform, but with care very little trouble was encountered. A concrete stiffener beam was constructed longitudinally under the concrete slab, midway between the wall and outside of the pier, and the outer and inner ends have a similar beam, the outer end being protected by a wooden fender. Ex-

pansion joints are provided about 40 ft. apart in the platform and beams.

Freight and Passenger Sheds.

These are two-story sheds of steel construction 1 150 ft. long and 360 ft. wide. There are four lines of railroad tracks inside the sheds extending their full length, and two lines of tracks outside the sheds, one on each side of the pier.

The lower floor is of 1 : 3 : 6 concrete, 10 in. thick, with surface of bitulithic, except a portion of two driveways which are wood block, and the upper floor is a 5 in. reinforced concrete slab with bitulithic surface except in the center shed, which has a granolithic surface. The second floor of all the sheds is designed for a live load of 500 lb. per sq. ft. and has a clearance of 22 ft. 8 in. above the first floor. On the outer edge of both outside sheds there is to be a conveyor gallery with top about 90 ft. above the ground, to be used in connection with a grain elevator it is proposed to build.

The sides and outer ends of the lower story between the columns, which are spaced 20 ft. on centers, are practically all doors 18 ft. wide and 22 ft. high, while the upper story has doors 18 ft. wide and 15 ft. high, making a total of 190 doors in all the sheds.

Fire System.

The entire area of both floors of the sheds is equipped with the automatic sprinkler system, and also a salt water fire system operated by two electrically driven centrifugal pumps.

Elevators.

There are eight electrically operated elevators, 18 ft. by 9 ft., for carrying freight or passengers from one floor to another, capable of lifting 12 tons at a speed of 25 ft. per minute. The cars are to have a head-room of 10 ft. in clear and to be operated with alternating current.

Winches.

Twenty-six winches are to be installed for handling cargoes, as follows:

Ten double-drum electric winches Type A, 2 drums and 2 winch heads directly geared to 35 h.p. motor operated by drum controller.

Ten single drum electric winches Type B, 1 drum and 2 winch heads driven by one motor.

Six double drum electric winches Type C, same as type A except motors are of 20 h.p.

Types A and B shall have duty of not less than 3 000 lb. at 250 ft. per minute on drums. Type C shall have duty of not less than 1 400 lb. at 350 ft. per minute on drums. For types A and B, General Electric or Westinghouse motors to be used, motors to be wound with 25 per cent. shunt field. Speed shall not exceed 650 revolutions per minute. Motors shall have rating of 35 h.p. for thirty minutes with actual rise in temperature not exceeding 75 degrees cent. over surrounding air. For Type C, motors shall have rating of 20 h.p. for sixty minutes at 75 degrees cent. heating and speed not to exceed 850 revolutions per minute. The current supplied to motors will be 220–250 volt D. C. Winding drums shall be designed for use of $\frac{5}{8}$ in. wire rope and not less than 30 in. in diameter. The face of the drums shall be not less than 24 in. wide. Winch heads shall be not less than 18 in. diameter of body, at least 15 in. width of face, and diameter of flanges at least 24 in. Both winding drums and winch heads shall be reversible on and keyed to main shaft.

Heating.

Air heaters are of two groups. Group 1 has combined capacity for heating 70 000 cu. ft. of air per minute through a range of 60 degrees with steam pressure of 2 lb. gage and velocity of air at rate of 1 000 lin. ft. per minute. Group 2 has capacity of 50 000 cu. ft. of air under same conditions. The fans are of the Multivane, double inlet type, capable of moving prescribed quantities of air against a static or frictional pressure of $\frac{3}{4}$ in. water column, with a power input to fans not exceeding 10 ft.-lb. per cu. ft. of air moved under maximum conditions. The motors are to be of variable speed induction type capable of continuous 25 per cent. overload and connected to fans with silent link belt drivers and pulleys to give required speeds.

Roofing.

The roofs are 5-ply, slag and asphalt coverings over 2 in. hard-pine roof boards nailed to spiking pieces fastened to the top of the steel purlins.

Steel (6 000 tons).

The steel superstructure is supported by columns 20 ft. apart longitudinally and varying from 33 ft. apart in the side

sheds to 40 ft. apart in the center shed, transversely, which carry heavy plate girders for the second floor and the light roof trusses.

Electric Heaters.

Electric heaters with a capacity of not less than 1 000 watts each are to be installed in six of the outside dry valve boxes. The equipment consists of one 2-pole, 440 volt, 25-ampere circuit breaker, automatic for overload and also for no voltage, with auxiliary contacts which close a 110-volt signal circuit when breaker is open. (A. C. service in both main and signal circuit.) They are to be used in groups of 4, and connected to 440-volt A. C. feeders.

Wiring.

Wire used for feeders on 440-volt, 250-volt and 110-volt circuits shall be rubber-covered cable, single conductor; conductors larger than No. 8 B. & S. shall be stranded insulation, of a compound containing 30 per cent. pure Para rubber. The greatest loss in potential between switchboard and farthest outlet must not exceed 4 per cent., 3 per cent. on feeders and 1 per cent. on branch circuits.

Lighting.

The interior lighting of the pier shall be Magda lamps of from 100 to 400 watts. The lamps shall contain a chemical to prevent blackening of bulb.

Power.

Two main feeders from sub-station supply 230-volt direct-current energy to a power loop which extends inside of outer walls of building. From this power loop shall be tapped six section mains, each of which shall have two pole, two coil, carbon break, circuit breaker with adjustable overload trip. Normal rating is to be 1 000 amperes, circuit breaker to trip for 200 amperes after eight seconds, and instantaneously for 300 amperes or over. Breaker shall be closed electrically by means of 230-volt auxiliary circuit.

Switchboard.

Copper straps shall be $\frac{1}{8}$ in. or $\frac{1}{4}$ in. thick, of suitable widths and not less than 98 per cent. conductivity. The height of switchboard shall not exceed 7 ft. 6 in., and total width shall not exceed 26 ft. There will be two rotary converter sets consisting

of one 3-phase, 6-pole rotary converter of 200 kw. capacity at 250 volts at direct current end; one 3-phase 60-cycle transformer, 6 600 volt, on primary side. One starting equipment for rotary. Rotaries to be self-starting on alternating current side, self-exciting compound wound. Momentary overload capacity not less than 50 per cent.

Viaduct.

A viaduct 1 180 ft. long, to connect the upper floor of the center of passenger shed with Summer Street, is being constructed. This consists of a roadway 44 ft. wide with 8 ft. sidewalks on each side. The roadway is supported by steel columns 46 ft. apart on centers with average span of 57 ft. (maximum 70 ft., minimum 46 ft.), carrying cantilever girders on each side of the roadway into which are framed floor beams 6 ft. on centers and 4 ft. deep. All the steel work is to be covered with reinforced concrete, and the roadway is built over a 10-in. concrete slab.

The columns are supported on reinforced concrete foundations from 16 ft. to 20 ft. square, resting on spruce piles, driven about 2 ft. 6 in. on centers.

There is a ramp to be built 50 ft. in width connecting the viaduct with D Street on a 4.7 per cent. grade. About 350 ft. of this ramp is a solid fill between masonry retaining walls supported on piles, and the remainder consists of four spans of steel structure similar to the main viaduct, about 200 ft. long.

Fish Pier, or Commonwealth Pier No. 6.

The contract for this pier was also entered into by the Harbor and Land Commissioners on September 23, 1910, with Holbrook, Cabot & Rollins Corporation, for the sum of $760 000. This pier is 1 200 ft. long and 300 ft. wide, of solid filling enclosed by masonry retaining walls with 23 ft. of water on all sides of the pier.

These retaining walls are not supported by piles but rest on a bed of riprap deposited under water, with the courses below low water laid by divers.

After this pier was practically completed and work had been started driving piles for the buildings to be erected by the Boston Fish Market Corporation, which has taken a lease of the pier, a movement of a portion of the wall on the easterly side of this pier took place, resulting in a movement outward of some 3 ft. as a maximum, and a maximum settlement of about 1 ft.

in a distance of 320 ft. This occurred at a point where the excavation for the building foundation had been piled some 10 or 12 ft. high on the edge of the wall, and this additional weight together with the vibration and compacting of the earth by the pile-driving resulted in the movement above described.

To remedy conditions, the following methods were adopted: First, the additional weight of excavated material was immediately removed. Second, immediately back of the ballast of the wall, five rows of spruce piles were driven 4.0 ft. apart on centers both ways. These were cut off at elevation 4.0 and capped by 6 by 10 Y. P. timbers laid flat, on top of which was laid a floor of 6 in. Y. P. planking. At the back of the last row of these piles was driven 6 in. Y. P. grooved and splined sheet piling, 25 ft. long. This was anchored back into the filling of the pier by means of $1\frac{1}{2}$ in. steel rods 54 ft. long, spaced 15 to 20 ft. apart and supported at the inner end by 6 in. sheet piling 15 ft. long and extending not less than 5 ft. on each side of the tie rods. Across and back of this line of sheeting was fastened an 8 in. by 8 in. oak timber through which the rods passed, with a $\frac{5}{8}$ in. steel washer between the oak timber and the nut. The pier was then refilled with cinders and apparently the measures taken have been successful in stopping any further movement.

A lease of this pier has been taken by the Boston Fish Market Corporation, and before another year it is expected that the entire fish industry which now occupies the old, picturesque buildings on T Wharf will be enjoying the advantages of all modern facilities for the rapid and economical handling, storing and shipping of fish in this new location.

The buildings are 55 ft. wide and about 750 ft. long, with a roadway 50 ft. wide paved with vitrified brick along each side and outer end of the pier, while the center portion of the pier is occupied with a roadway 86 ft. wide paved with granite blocks, with a railroad track in the center of the street.

At the outer end is the administration building, while at the street end is the cold-storage and power-plant house. Two lots on the southerly side of Northern Avenue, one each on the east and west side of D Street, have also been leased to the Boston Fish Market Corporation, and a building is now being erected on the easterly one.

The buildings were expected to be ready for occupancy on October 1 of this year, but the time will probably need to be extended for a month or two.

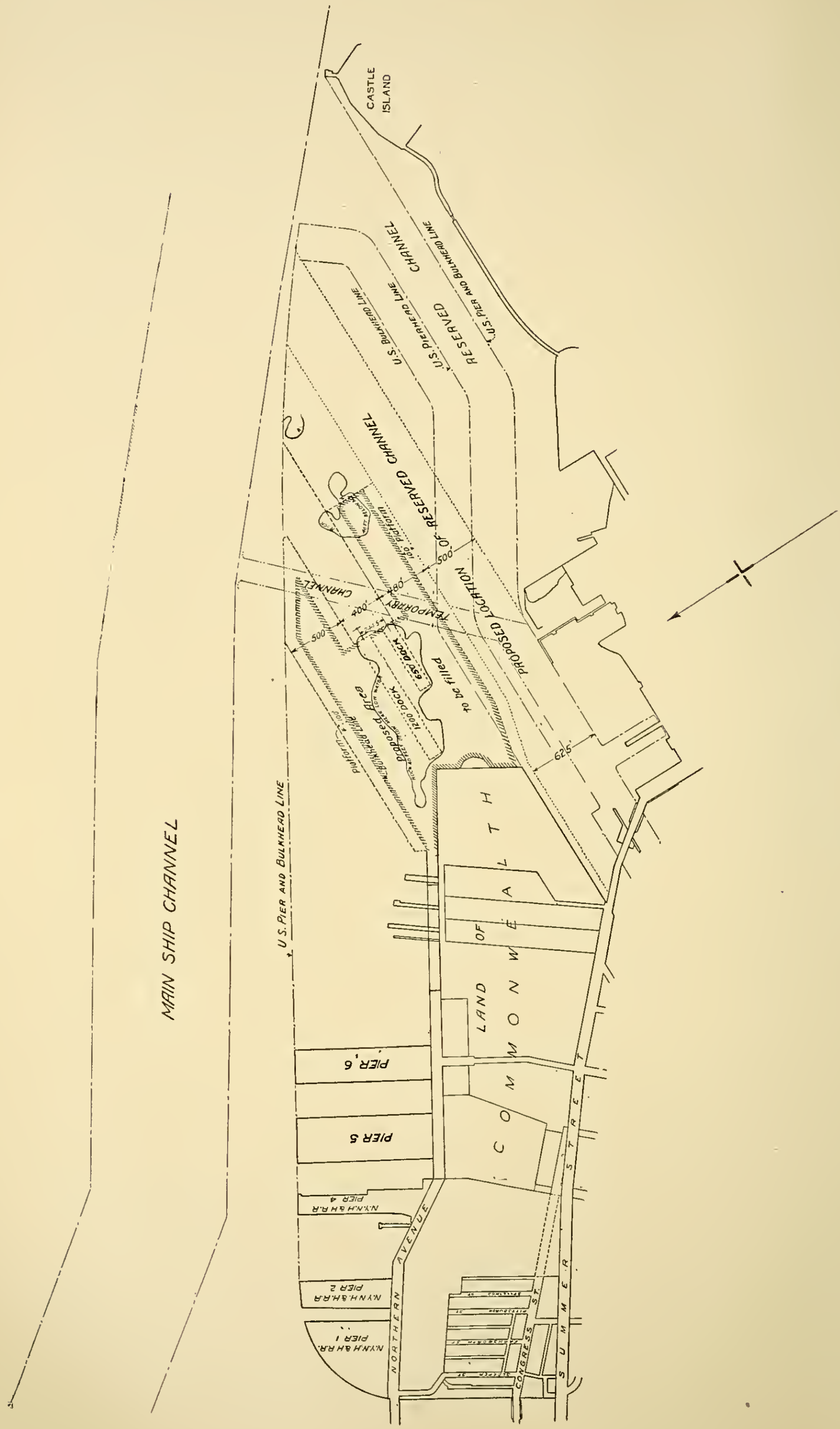
East Boston Work.

Under the direction of Mr. Henry V. Macksey, studies and estimates were made for the development of that portion of the harbor, and the directors voted to set apart $3 000 000 from the $9 000 000 appropriated, for that purpose. The plan proposed the construction of a pier 1 200 ft. long and 250 ft. wide, with 40 ft. of water at the sides and a two-story shed covering the greater portion of the pier. As a preliminary to that, a contract was advertised and bids were received for the construction of a timber bulkhead about 11 000 ft. long enclosing about 170 acres, which was to be filled to elevation 14.0 and used for the industrial development of this section. Before the contract was awarded, a suit was brought by a land company questioning the right of the directors to carry out the proposed work, so the work was abandoned for the present. Since that time a taking was made of what is known as the old Eastern Pier, which is located immediately northwest of the Boston & Albany piers, and can be served from the Boston & Albany Railroad tracks and the Boston & Albany grain elevator with very little additional work.

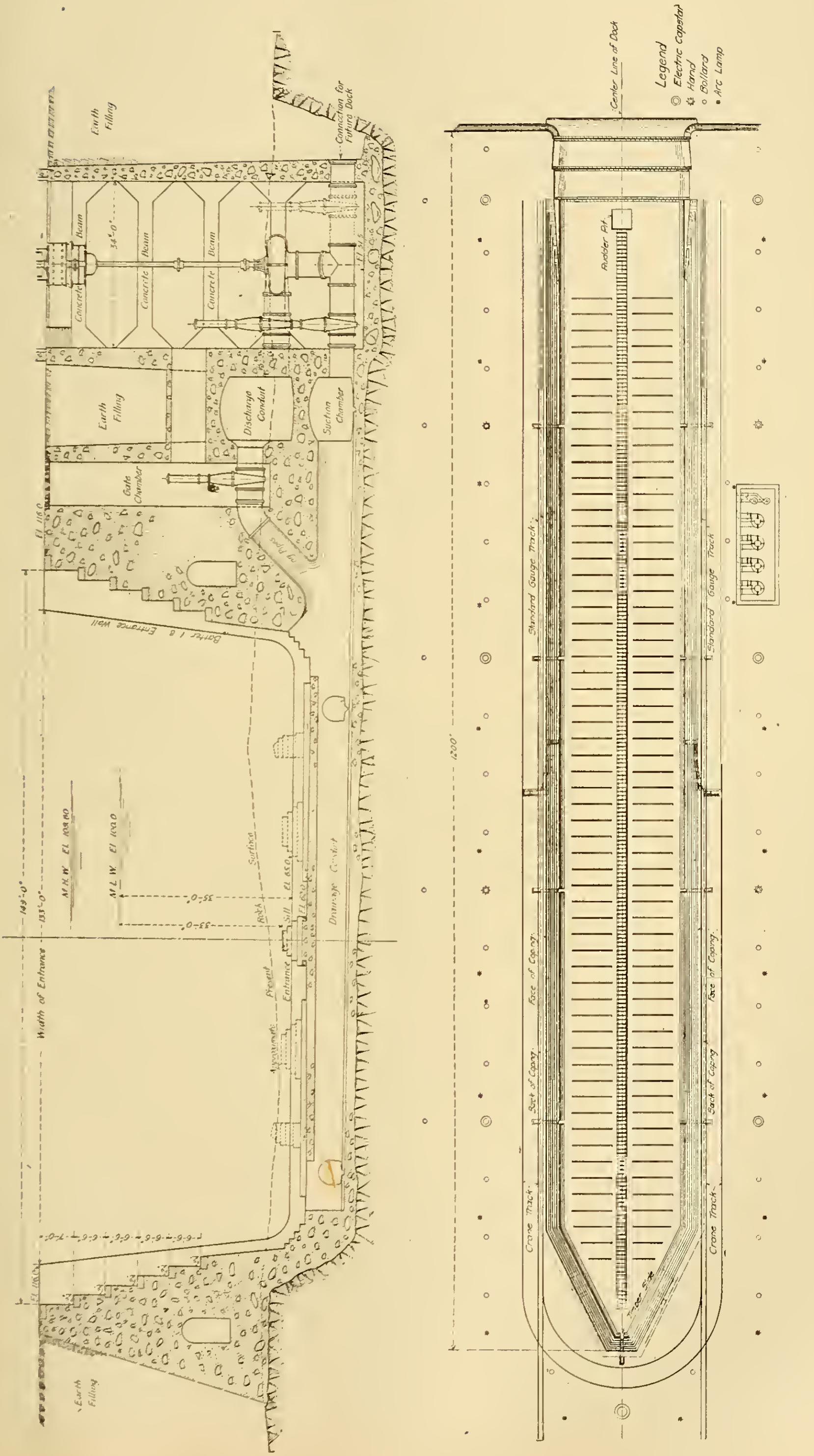
Dry Dock.

The directors have voted to set aside $3 000 000 for the construction of a large dry dock on the South Boston shore at a point where the surface of a ledge rises above a plane of 40 ft. below mean low water. The location selected extends easterly from the northeasterly corner of the present bulkhead east of the property occupied now by the Boston Molasses Company towards Castle Island and north of the Reserved Channel. The area was thoroughly explored with diamond drill borings early this spring, and the results were very satisfactory and seemed to indicate that the ledge, which was of a slaty nature, would furnish a suitable foundation for such a structure without developing open or water-bearing seams, and that the stone would probably be suitable for use in concrete and as cyclopean stones in the side walls of the dock.

The plans as proposed at the present time call for a dock 1 200 ft. in length over all from the outer sill to the inside of the coping at the head, a width of 120 ft. 3 in. on the sill at the bottom, and 134 ft. at the coping entrance, with a width of 150 ft. between copings in the body of the dock. The depth over the sill is to be 35 ft. at mean low water and 44.5 ft. at mean high water. The bottom of the dock is 3 ft. below the sill, and the



GENERAL LOCATION PLAN.



SECTION AND PLAN OF PROPOSED DRY DOCK.

keel blocks are to be 5 ft. high, spaced not more than 4 ft. on centers and part of the way to be 2 ft. on centers. There are to be five altars 2 ft. in width. The bottom and sides of the dock are to be of concrete and cyclopean masonry, with granite tops for the altars and for the coping at the top of the side walls. The pump house is to be about 90 ft. long and 28 ft. wide and is to contain four 54-in. centrifugal pumps, electrically operated, with an average capacity of 100 000 gal. per minute at heads varying from zero to 50 ft. The dock would contain about 57 000 000 gal. of water, and it is expected it can be emptied in from $2\frac{1}{4}$ to $2\frac{1}{2}$ hr., and can be filled in from one half to three quarters of an hour.

It is planned to use a floating caisson for a gate, with ten 30-in. pipes for filling, and there will be 5-ft. by 10-ft. filling conduits in each of the side walls.

Up to the present time there has always been great opposition to the building of a dry dock by the Commonwealth, but to-day opponents appear to have become reconciled to the idea. What other people think of us in this respect may be understood in some degree by the following clipping taken from a London periodical devoted to maritime affairs in its issue of July 23, 1913:

"Across the Atlantic there is not on the whole of the American and Canadian seaboard a dock which could take the *Olympic*, nor is there, we imagine, one which could take the *Lusitania* or the *Mauretania*. To sink half a million pounds sterling in a dock for three ships certainly does not seem to be very sound finance, but actually it would be just ordinary business for somebody to do so on the Atlantic seaboard of the United States. It might be better even than ordinary business, because some highly remunerative contracts would be practically certain to be sent in the direction of the enterprise. . . . In any case, it is odd to find an up-to-date maritime country like the United States without docking accommodations adequate to the demands of the shipping-using ports on its most important seaboard. . . . Indeed, the general indisposition to facilitate the development of the passenger ships using the ports is one of the least easy things about American enterprise to understand."

Belt Line Railroad.

During the summer of 1912 surveys were made for an outer belt-line railroad connecting with all the railroads entering the city, and rough estimates were also made for a tunnel under the harbor between South and East Boston and for connecting the New Haven and Boston & Albany Railroad.

Summary of Work Done.

In eighteen months a new and modern railroad and steamship terminal 1 200 ft. long and 400 ft. wide has been constructed with 40 ft. of water on both sides of the pier, and a line of one of the largest transatlantic steamship companies is using it for the receipt and delivery of passengers and cargo.

A taking has been made of the Eastern Pier (so-called) on the East Boston side of the harbor and plans are under way for the development of this property in a similar manner to Pier No. 5 at South Boston.

Preliminary plans and specifications are under way for the construction of the largest dry dock in the world.

A taking is being made of the property east of Jeffries Point in East Boston, for the purpose of industrial development.

There are now six new steamship lines entering the port of Boston in regular service that had never before called at this port. These are as follows:

Hamburg-American Line, bi-weekly service, in and out.

North German Lloyd Line, three weekly service, in.

Russian American Line, three weekly service, in.

Navigazione Generale Italiana Line, four weekly service, in and out.

Fabre Line, monthly service, in and out.

Pacific Coast Line, bi-weekly service, in and out.

In addition to these, beginning next year, the Cunard Company promises to put on the *Carmania* and *Caronia*, 20 000-ton ships, thus giving weekly service to the channel ports via their line.

To Be Done.

With the opening of the Panama Canal, Boston ought to have a noticeable increase in the amount of shipping using this port.

The directors have made a start in furnishing inducement for steamship companies and travelers to use this port. With the assistance of the railroads and the business men of this section, there should be no difficulty in getting a good share of the new business as well as taking care of some of the business that New York, on account of lack of room, is unable to care for.

In September, 1913, the directors were requested to provide accommodations for a steamship line from Russia, using a part of Commonwealth Pier 5. The first steamer arrived October 7 and was obliged to dock elsewhere; so that business appears

to be coming faster than the facilities can be provided for it, even with our best endeavors to keep ahead of the demand. Is it too much to expect that Boston is now beginning to assume once more the place in maritime affairs she held a century ago, when her ships were seen in every quarter of the globe and the foundation of many of the present-day fortunes of Bostonians were first laid?

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1913, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

George Daniel Rosenthal.

MEMBER ENGINEERS' CLUB OF ST. LOUIS.

GEORGE DANIEL ROSENTHAL was born at Krementschug, Russia, January 6, 1869. His death occurred in New York City, on the eighteenth day of May, 1913. He was the son of Herman and Anna Rosenthal. He was educated in the University of Poltawa, Russia, which he attended during the years 1879–81 inclusive; came to United States with his parents in 1882 and later attended school at Mitchell, So. Dak., from 1883–86.

He entered the service of the General Electric Company in 1887, and continued with them until the time of his death. He was employed at the Harrison, N. J., factory from 1887 to 1890; at the Chicago office, 1890–1892, and at the St. Louis office since the latter date. Coming to St. Louis to take charge of the detail and supply department, he was within a few years promoted to the position of manager, and retained this title until shortly before his death, when he was promoted to the position of district manager, the St. Louis office having been made a district office at his initiative.

In addition to his connection with the General Electric Company he had served as vice-president and manager of the P. C. Murphy Trunk Company for several years past. He was also a director for several years of the Jefferson City Light, Heat and Power Company, the Washington Bank of St. Louis, and several other corporations.

Mr. Rosenthal was prominent in the political life of St. Louis, having been influential in the nomination of Mayor Kreismann, and was closely identified with his administration in many ways. He was nominated for the school board of St. Louis but withdrew before the election in the interest of his party and friends.

He was a member of the Mercantile Club, City Club, Liederkranz Club and the Engineers' Club of St. Louis, which he joined February 19, 1902. He was a thirty-second degree Mason, Knight Templar, Shriner, member of the Jovian Order and the St. Louis League of Electrical Interests.

Mr. Rosenthal was married, April 27, 1896, to Miss Josephine Murphy, of St. Louis, and his family consists of six children, all of whom survive him.

Mr. Rosenthal was a very capable, energetic and successful business man. His disposition was cheerful, and he was an optimist in his view of life. He was a good type of a self-made man, his success being entirely due to his ability and energy. He was original in thought, and some of his characteristic expressions will long be remembered. He was extremely loyal to his friends; and his friends, not only in the city of St. Louis, but throughout the country, were legion. He was devoted to his home and family. Mr. Rosenthal was one of whom it could be said, " He was a friend of man."

H. H. Humphrey.
A. S. Langsdorf.
H. Spoehrer.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. LI. | DECEMBER, 1913. | No. 6.

WATER METER PERFORMANCE IN ST. LOUIS.

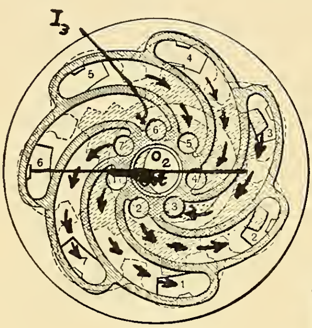
BY FRED. L. BOCK, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, April 16, 1913.]

As early as 1880 the water department had a few water meters in service. The only meter then known was the Worthington plunger, which is very similar to a double piston pump. A so-called modern type of water meter such as the rotary piston began to displace the plunger type about 1892 and has, till recently, continued to be the type preferred by the department. The disk and velocity types followed later, but the velocity type was considered too inaccurate on small flows and the disk type as unreliable. The water department has changed its policy and is now giving preference to the disk and velocity types over the more expensive rotary.

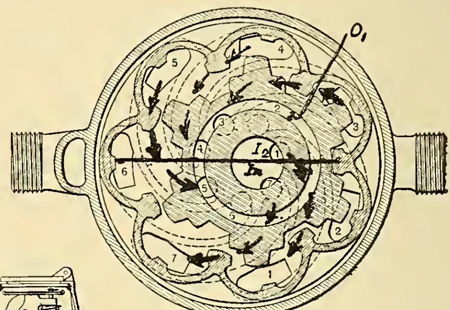
It is essential to know the construction and operation of the various types in order to compare their performances and discuss their adaptability to various kinds of service. The oldest type, the duplex plunger, is mentioned only as a matter of historic interest for it is now obsolete for measuring water supplies. It is still used, though, to measure hot water, beer, oil and other liquids which would ruin the hard rubber parts used in all modern types. It will suffice to describe its operation as similar to that of a *duplex water pump* with its parallel cylinders and sliding valve. A driving arm and pawl transmit the reciprocating motion of the plunger to a ratchet wheel on the under side of the recording dial. The other types can be classed as modern and are of the same general scheme; they differ principally in their measuring chamber and are classified accordingly. The water

passing through the measuring chamber operates a hard rubber piston, disk or wheel. Within the same casing, lubricated by the circulation of water, is a train of bronze gears which reduces and transmits the piston motion through a stuffing-box to the recording dial. The dial and gear train spindles are connected by a pair of gears which can be changed so as to correct any small inaccuracies of registration. The modern types may then be classified as rotary, disk and velocity. There are several models on the market which are a combination of these. The Venturi



SECTION A-B

Fig 2



SECTION C-D

Fig. 3

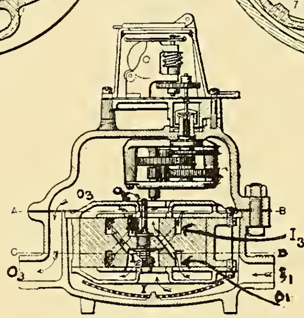


Fig 1

Crown Meter.

meter is not considered in this paper, for it is not used on ordinary city service connections.

The Crown was the first of the rotary piston type, and was introduced in St. Louis early in the nineties. The hard rubber piston is of such specific gravity that it weighs in water about 20 per cent. of its weight in air. Referring to Fig. 1 the water enters the meter at I_1 and, after passing through the strainer at the bottom, it is ready to be distributed from the pocket I_2 to the measuring chambers on one side of an assumed diametrical line (in Fig. 2 and 3), while those measuring chambers on the other side of it are discharging, thereby causing the piston to rotate about its own axis and revolve about the axis of the

measuring chamber; that is, the piston rotates once in every six revolutions. The rotating motion is evident from the fact that the projections on the piston are one less in number than the chambers into which they fit. To follow the course of the water it must be borne in mind that the pocket I_2 at the center and bottom of the piston is continually open to the inlet, while the corresponding pocket O_2 at the top is always open to the outlet. Again, the circular groove I_3 is continually open to the inlet, being connected to pocket I_2 by ducts through the piston, and the corresponding groove O_1 in the bottom is similarly connected with the outlet pocket O_2 at the top. A section *CD* through the bottom of the measuring chamber shows (in Fig. 3) the water entering chambers 1 and 7 and about to enter 2 from the inlet pocket I_2. At the same instant, on the other side of the diametrical line, water is discharging from chambers 3, 4 and 5 into the outlet groove O_1. At this instant chamber 6 is entirely closed and is about to be opened to the outlet groove O_1. Following the same analysis of the upper section *A-B*, shown in Fig. 2, the water is also entering the chambers 1, 2 and 7 but is supplied from the groove I_3 at the top of the piston. The chambers 4 and 5 are discharging into the outlet pocket O_2 at the top of the piston. Thus at this instant the assumed diametrical line divides the measuring chamber so that on the one side two chambers are being filled from both top and bottom and the third from the top only, while similarly on the other side two chambers are discharging at the top and bottom, and the third from the bottom only. The remaining seventh chamber is inactive and closed to both inlet and outlet.

[NOTE. — The mathematical discussion of the Crown Meter and cuts illustrating the discussion are not printed.]

The Crown was soon followed by another rotary, known as the Hersey Rotary. The general arrangement of the parts, piston and chamber walls bears such similarities and contrasts to the Crown meter, just described, that one might easily imagine the Crown piston and chamber adapted to a circular motion instead of a series of swinging motions. The water enters the measuring chamber through the ports in the bottom, and leaves through the opening at the center of the top.

The hard rubber ring and piston are hollow, and the piston is of such specific gravity that it weighs in water about 35 per cent. of its weight in air. Fig. 4 is a horizontal section through the measuring chamber, showing the position of the piston with respect to the inlet and outlet ports in the bottom. At the

instant shown, water enters the chambers E through the inlet ports 1, 2, 3, 4 and 6 in the bottom. It will be noticed that the six inlet ports are twice as large in area as the outlet ports 7, 8, 9, 10, 11 and 12, because there is a corresponding set of outlet ports in the top plate. At the same instant water is discharging from chambers D through the outlet duct ports 10 and 11 to the cylindrical opening in the center of the piston, which in turn is always open to the outlet of the meter. The inlet port 5 and outlet port 12 are on the point of opening. In a complete revolution every point in the piston describes a circle of radius PC. In its motion it is quite evident that all surfaces of contact are sliding, in contrast to that of the Crown, where the sides are in rolling contact while the top and bottom only are in sliding contact. The increased wear of all sliding surfaces in the Hersey Rotary is very noticeable, and the friction caused by the sliding contact of these roughly worn surfaces seems to account for its marked loss in sensitiveness. The volume discharged per revolution is the volume of the chamber minus that displaced by the piston and the cylindrical outlet pocket in its center.

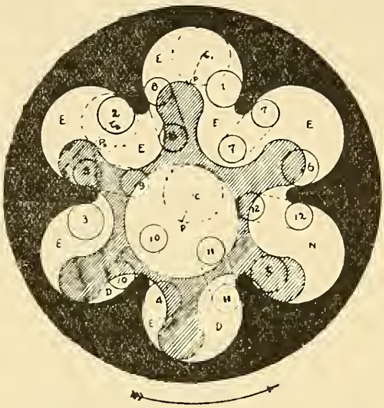


Fig. 4. Section of Hersey Rotary Meter.

Another meter classed as rotary is the Empire. The motion of the ring-shaped piston might be described as oscillating. The center of the piston (Fig. 5, 6, 7 and 8) describes a circle about the center of the chamber, while the slot in the ring reciprocates along the stationary diaphragm. The circular motion is controlled by a hard rubber pin in the center of the piston, sliding in a circular ring B concentric with the chamber. In Fig. 5, 6, 7 and 8 the water enters port D in the bottom plate and discharges from E in the top plate.

The piston is so controlled by the diaphragm C and ring B that there is always some point a on the outer edge of the piston in contact with the outer chamber wall, while diametrically opposite on the inside of the piston ring there is continually a point b in contact with the inner wall, the guide ring B. Consequently this diametrical line of contact ab separates the

inlet from the outlet spaces. As the pressure acts in a direction against the projection of this diametrical line, it acts parallel with the contact surfaces, and thus excessive friction is avoided. In Fig. 5 the spaces 1 and 3 are filling while 2 and 4 are discharging, thereby causing the piston to move in a direction indicated

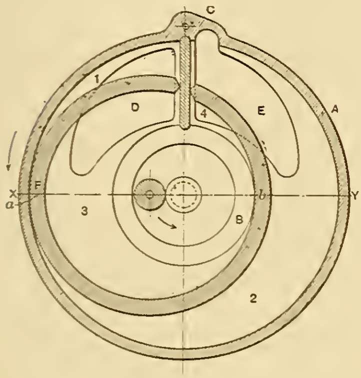


FIG. 5.

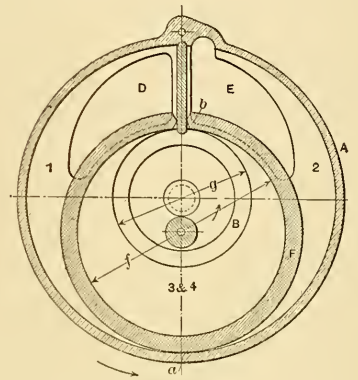


FIG. 6.

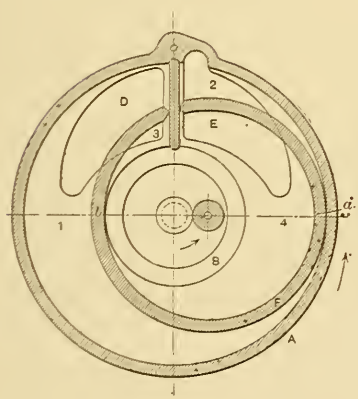


FIG. 7.

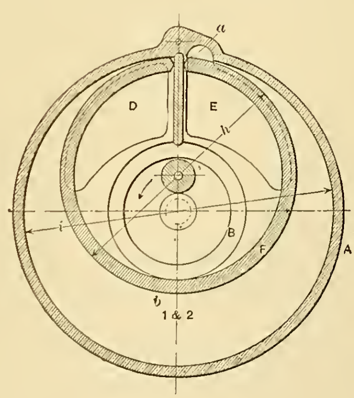


FIG. 8.

SECTION OF EMPIRE ROTARY METER.

by the arrow. On moving to position in Fig. 6 the inlet space 1 has enlarged; 3 and 4 have combined and are about to discharge through port *E*; while the outlet space 2 has diminished. Fig. 7 shows the inlet space 1 still enlarging, and at the same time the newly formed inlet space 3 and the outlet spaces 4 and 2 as diminishing. In Fig. 8 the inlet space 1 has become a maximum and is about to discharge and become 2 of Fig. 5.

This would bring the piston into its original position of Fig. 5. From the foregoing explanation it is quite evident that the annular space between the outer and inner walls *A* and *B* of the chamber is filled and discharged in each oscillation of the piston.

The Union Rotary Meter, as shown in Fig. 9, is another of the rotary type. The design of the rotors is similar to that of a well-known type of blower. The rotors are made of hard rubber and are fixed in relative position by two elliptical hard-rubber gears. The volume per revolution will be equal to the volume of the chamber minus the volume displaced by the two rotors. The direction in which the rotors turn is controlled by a V-shaped guide vane at the inlet which divides and deflects the incoming stream so that it flows around by the wall of the chamber to the outlet.

The most popular meter in sizes smaller than 3 in. is the disk type (Fig. 10 and 11), so-called from the shape of its hard-rubber piston. The disk-shaped piston may be said to mutate or wobble about the ball and socket bearing at its center. The chamber in which the disk mutates may be described as a portion of a sphere enclosed by the zone generated by the revolution of an arc about the diameter as an axis. There are two shapes of disk, one flat and the other conical, requiring a corresponding difference in the chambers. Fig. 10 shows a meter with a flat disk; the top and bottom of the chamber are conical in shape and symmetrical. Fig. 11 shows a meter where the disk is conical and the bottom of the chamber flat. A diaphragm extending from the outer wall of the chamber to the ball of the disk at the center divides the chamber so that the water entering at one side of the diaphragm travels around the annular-shaped chamber, forcing the disk before it, and is discharged from the opening at the other side of the diaphragm. The two lines of contact between the disk and top and bottom of the chamber divide it into four parts, of which two are continually filling and the other two discharging. This results in a continuous flow, and the volume displaced per revolution is the volume of the chamber minus that displaced by the disk. The equations of the volume discharged per mutation are shown in Fig. 12 and 13.

The foregoing types measure water by positive piston displacement, in contrast to the velocity type, which measures the volume of flow by its velocity. These velocity types operate as reaction water wheels. Fig. 14 shows a velocity type meter where the water enters at the center of the wheel, reacts against

FIG. 9. UNION ROTARY METER.

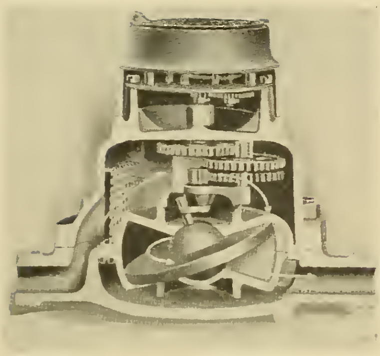


FIG. 10. FLAT DISK.

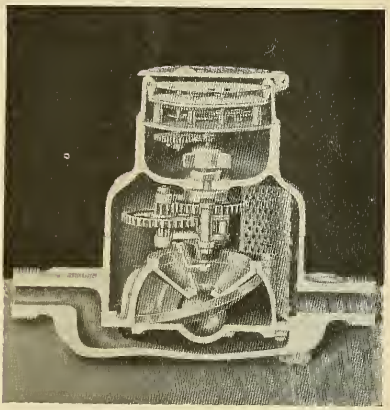


FIG. 11. CONICAL DISK.

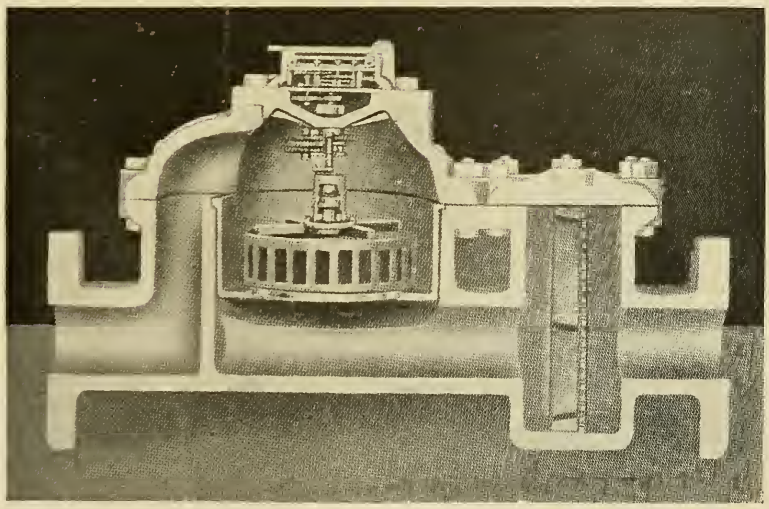


FIG. 14. METER OF VELOCITY TYPE.

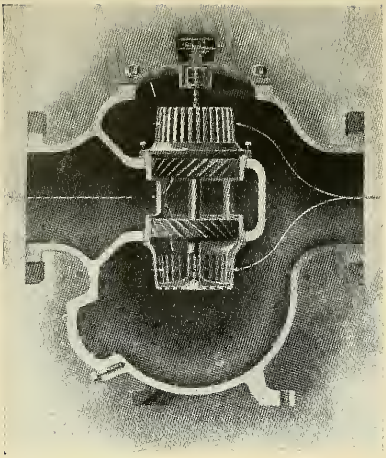


Fig. 15. Meter with Double Balanced Wheel.

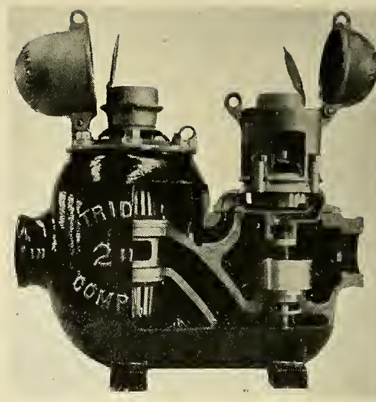


Fig. 16. Compound Meter.

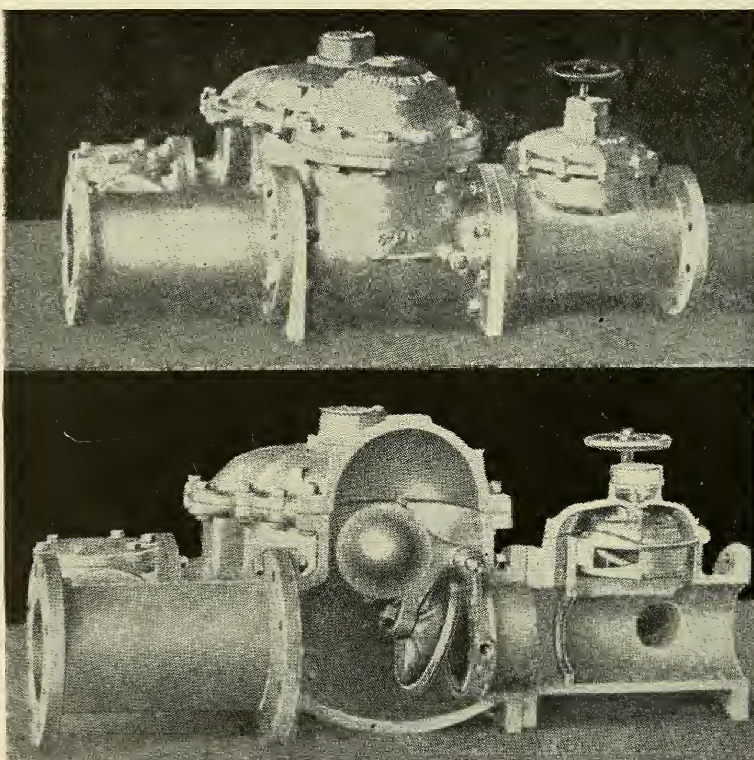
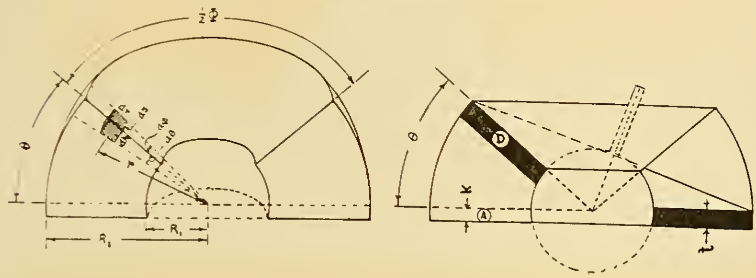


Fig. 17. Detector Meter.

the curved vanes and discharges at the outer edge. Another design of velocity meter is shown in Fig. 15, where two reaction wheels are mounted on the one shaft so that the end thrust is balanced by the water reacting against the blades from both ends of the runner. The weight of the runner in water is carried by agate or hard-rubber bearings at the bottom of the shaft.

FIG. 12. DISCHARGE PER MUTATION.



$R_1 = 0.615''$ $R_2 = 1.615''$ $\theta = 41°17' = 0.229\pi = 0.722$ Radians $t = 0.18''$ $K = 0.12''$

$dV = dr\ dh\ ds$ (1) As $dh = r d\theta$ and $ds = r d\phi$

$dV = r^2 dr\, d\phi\, d\theta$ (2) $\therefore$ $V_s = \int r^2 dr\Big]_{R_1}^{R_2} \int d\phi\Big]_0^{2\pi} d\theta\Big]_0^{\theta} = \frac{2\pi}{3}[R_2^3 - R_1^3]\theta$ (3)

Vol Displaced $= V = V_s + V_A - V_D$ (4) As $V_A = K\pi(R_2^2 - R_1^2)$ $V_D = t\pi(R_2^2 - R_1^2)$

$\therefore V = \frac{2\pi}{3}[R_2^3 - R_1^3] + \pi(R_2^2 - R_1^2)(K - t)$ (5)

$V = 5.61$ cu in By test $V = 5.57$ cu in

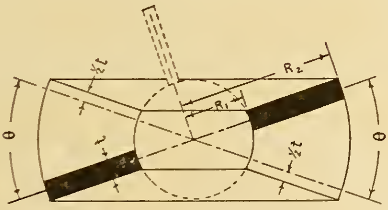


FIG. 13.

$R_1 = 0.59''$ $R_2 = 1.54''$ $\theta = 38°40' = 0.215\pi = 0.676$ Radians

$V = V_s = \frac{2\pi}{3}(R_2^3 - R_1^3)\theta = 4.88$ cu. in. By Test $V = 4\ 94$

From tests made on the various types of velocity meters the double balanced wheel appears to be the most sensitive to low velocities.

Fig. 16 shows a compound meter which is designed to give a minimum impedance on large flows and to measure accurately small flows. On small flows the disk meter operates, and when its capacity is reached the weighted valve is unseated, closing

the small meter and opening the velocity meter to operate on the larger rates of flow.

Meter manufacturers in the past have been endeavoring to construct a meter suitable for fire-protection service, and up to the present time only one make has been approved by the fire underwriters. The value of such a meter for detecting the theft of water from fire protection services will be understood by any one familiar with water works. A striking example of its use was made in a city of Michigan, where after installing one of these meters on the fire service of a manufacturer, it was found that water was being stolen at the rate of about $5 000 a year. From the evidence it appeared that this theft had been going on for about four years; the jury rendered a verdict against the defendant for $15 842.76. Fig. 17 shows such a meter. The main pipe is equipped with a weighted check valve in front of which is a baffle ring to deflect about 5 per cent. of the main-pipe flow through the proportional meter. A metered by-pass half the diameter of the main line connects the two sides of the check valve. An annular groove in the seat of the check valve is opened to the atmosphere when the valve is seated. This arrangement holds the valve closed under a pressure equal to the difference between the total resultant hydraulic pressure on both sides of the valve gate and the total atmospheric pressure on the groove of the valve seat. The groove in the seat is of such area that the check valve is unseated when the pressure drop around the valve is 6 per cent. The metered by-pass registers the entire flow at rates which are not sufficient to open the valve gate. On flows that keep the check valve open the proportional meter operates so as to register that portion which passes through the main line. The function of the ball weight is to reseat the check valve, for it would tend to float, as no excess pressure is created above it when unseated. Fig. 18 serves to illustrate the proportional amounts and accuracy of registration on both the main line and by-pass at various rates of flow through a 4 by 2 in. detector meter. This detector meter is quite adaptable to services where both large and small rates of flow are desired. The feature in the detector of measuring large flows by proportion is used in a so-called "proportional meter." One model is a straight section of pipe with a baffle ring to deflect a portion of the water through a small meter, calibrated to register directly the total flow. The other model operates in the same way, but in addition is equipped with a by-pass, so that the meter can be repaired without interrupting the water service.

The remainder of this paper will be devoted to the comparative performances and characteristics of the various types.

The curves of Fig. 19 and 20 serve to show the comparative impedance of the different types and sizes at various rates of flow. From these curves it is evident that near full capacity the impedance of the velocity type is much less than that of the disk type, which in turn is less than that of the rotary. On their smallest flows the impedance of any type is negligible. The fact

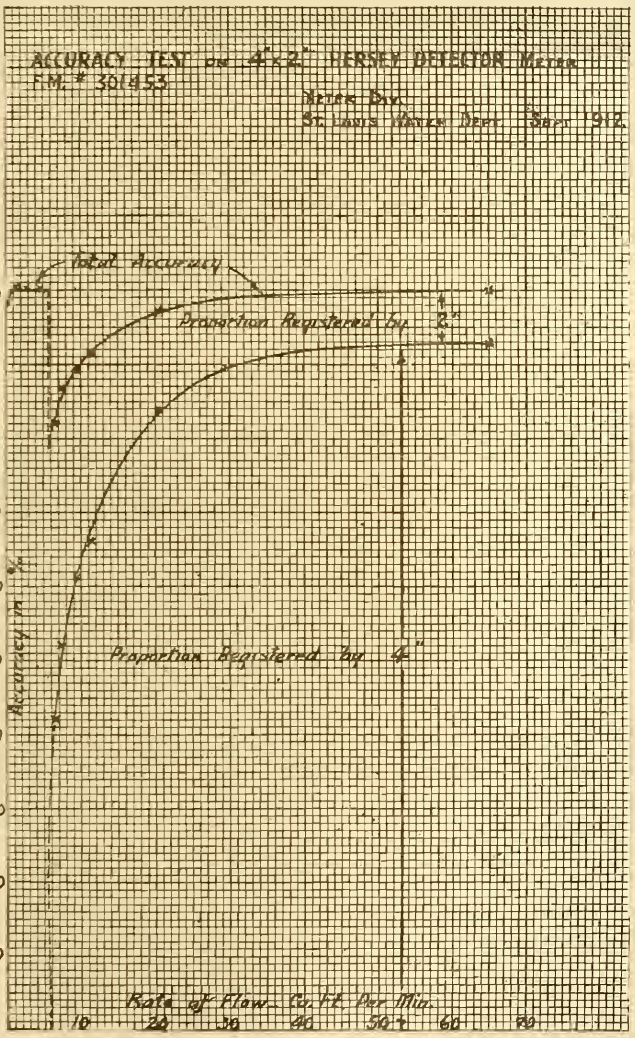


Fig. 18.

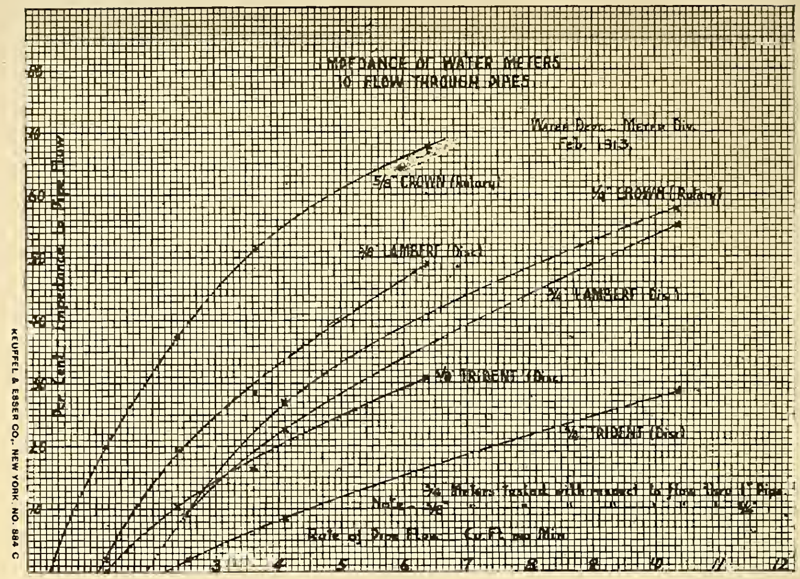

IMPEDANCE OF WATER METERS
TO FLOW THROUGH PIPES.
Water Dept. Meter Div.
Feb. 1913.
5/8" CROWN (Rotary)
3/4" CROWN (Rotary)
5/8 LAMBERT (Disc)
3/4 LAMBERT (Disc)
5/8 TRIDENT (Disc)
3/4 TRIDENT (Disc)
Per Cent Impedance to Pipe Flow
Rate of Pipe Flow Cu. Ft. per Min.
KEUFFEL & ESSER CO., NEW YORK. NO. 884 C

FIG. 19.

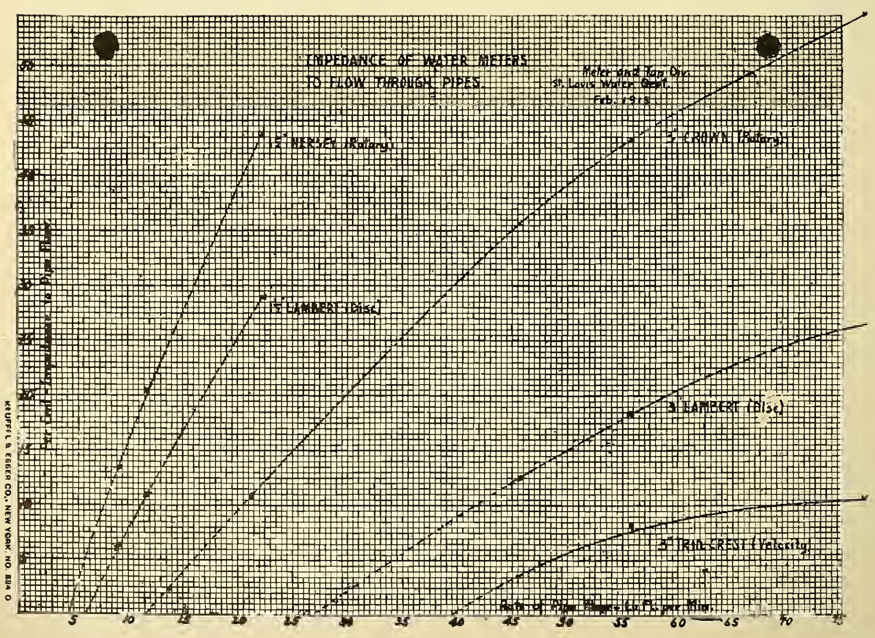

IMPEDANCE OF WATER METERS
TO FLOW THROUGH PIPES.
St. Louis Water Dept.
1½" HERSEY (Rotary)
1½" LAMBERT (Disc)
3" CROWN (Rotary)
3" LAMBERT (Disc)
3" TRIDENT CREST (Velocity)
5
10
20
25
35
40
45
50
55
60
65
70
KEUFFEL & ESSER CO., NEW YORK. NO. 884 C

FIG. 20.

must not be overlooked that the full capacity of the disk type can, within limits, be easily regulated by the size of inlet and outlet passages to the measuring chamber. The meter manufacturers are quite uniform in the matter of full capacity, disk mutations per cubic foot, and the size of measuring chamber. This uniform practice of piston speed represents the maximum that is consistent with a good wearing efficiency.

It has been the experience of the department that rotary meters lose their accuracy and sensitiveness gradually. They will still continue to operate when they become so worn as to register as low as 60 to 80 per cent. of accuracy. These large inaccuracies can be attributed to the wearing of the comparatively large sliding surfaces exposed to the grinding action of grit in the water. This excessive wear results in a large amount of play between the piston and the chamber, permitting water to slip through without acting on the piston. The sliding surface exposed to grit is far greater in the rotary type than in any other.

Our observations indicate that the disk type maintains its accuracy better than the rotary. The disk type generally maintains an accuracy of 90 per cent. or better until it fails entirely. The maintained accuracy can be explained by the fact that the wearing surface of a disk is concentrated at the ball and socket bearing. This affords only a small surface exposed to grit and slippage. When the wear in the bearing allows sufficient play, the edge of the disk will bind in the chamber and so cease to operate and probably break. These disks are cheap to replace as compared to the pistons of the rotary type.

The velocity type, due to the small wearing surface exposed to grit, maintains its accuracy very well. It is used only in the larger sizes, that is, 3 in. and above, and is by far the cheapest in first cost and maintenance. It is also most accessible for repairs and is especially adapted to the services of consumers where large rates of flow are used, or where water is used only at long intervals of time. It is not particularly adapted to services that have small fixtures and openings, for the velocity type will not register leaks and will only partly register the small streams.

The disk type is about one third less in first cost than the rotary, due in a measure to the greater amount of hard rubber and machinery necessary in the piston and chamber of the rotary type.

The disk type in the smaller sizes is more accessible to

repair. One make embodies in the design properties for incurring a minimum amount of damage in case of freezing. The bell shape of the upper casing causes the stress of freezing in a vertical direction. The bottom is so designed that it will break before the other parts are permanently distorted. When the bottom is released the measuring chamber is so designed as to be free to fall apart in case it is subjected to an internal stress. Our experience finds that on replacing a broken bottom of such frozen meters the accuracy has not been affected. And so the measuring chambers of many makes of disk meters have special features which are advanced as arguments in their favor. The wearing surfaces of the measuring chamber of a disk meter are confined to the ball and socket bearing and the diaphragm. To reduce the cost of repairing a badly worn ball-socket bearing, some firms construct the disk chamber in three parts instead of two, so that only the top and bottom plates need be replaced when the bearing is worn. Some also construct the ball of the disk so that it can be taken apart and adjusted for wear by the insertion of paper between the halves. Excessive wear on the diaphragm caused by the tendency of the disk to rotate about its spindle must be avoided if the meter is to be reasonably accurate on small rates of flow. Several firms entirely avoid this wear on the diaphragm by a thrust roller which is placed in the edge of the disk at a point diametrically opposite the diaphragm and so takes the side thrust while oscillating in a vertical slot in the side of the measuring chamber. From the data which the department now keeps it will be able in a few years to determine whether or no this feature is an advantage. As previously shown, some meters have flat disks and others conical. The advantage claimed for the conical-shaped disks is that any section is a curve, so that it will embody the strengthening effect of an arch. Many firms strengthen the flat disks by a steel reinforcement. In the case of the flat disk the horizontal thrust of the water in motion is less than in that of a conical disk and is proportional to the sine of the angle between the disk and the horizontal.

The gear train in any meter which transfers the piston motion to the dial is generally made of phosphor bronze pinions, gears and shafts, while the frame is bronze. One difficulty experienced in the past with gear trains in St. Louis water is a heavy white deposit of calcium carbonate which becomes so thick as to interfere with their operation. This calcium deposit also closed strainers and passages and covered pistons and

chambers with a hard white deposit. It is almost impossible entirely to remove this coating by a mechanical process. The department now removes this coating quickly and cheaply with a dilute solution of muriatic acid and so restores to service many meters and parts which were formerly condemned for scrap. The pistons of rotary meters being hollow and having small openings for the admission of water resulted in a deposit of calcium carbonate on the inside of such pistons. For example, a piston taken from service weighing ten and one-half pounds, after treatment in acid lost two and one-half pounds. In all similar cases, the piston becomes more buoyant and responds to small rates of flow, whereas it failed to do so before the acid bath. Another difficulty experienced is in the gear train, and is due to the soluble salts in our water which set up an electrolytic action between the parts having different zinc constituents. That is, the parts containing more zinc when exposed to the action of the electrolytic solution become electro-positive with respect to the parts containing less zinc, causing the parts high in zinc to disintegrate and leave the copper constituent in a porous and brittle form. This electrolytic action was recognized by Mr. Monfort, chief chemist of our water department, and described by him in a paper before the water-works convention at New Orleans in 1910. As a remedy he suggested that the various parts should as nearly as possible be of the same alloy. Accordingly a change was made by one firm in the construction of the frame posts of the gear train so as to conform with Mr. Monfort's suggestion. The posts were combined with the upper part of the frame to make a unit and so lessen the parts that might otherwise be of a slightly different alloy. A clause containing the feature of a uniform alloy throughout the gear train has been embodied in a specification under which the city purchases meters. To prevent corrosion and increase the wearing efficiency, one firm constructs a gear train of hard-rubber gears, hard-rubber thrust bearings, and phosphor-bronze pinions. Some firms use a gear train in which jewels serve as thrust bearings.

Recently the case of a meter becoming fast came to our attention, and such cases are so rare among the modern types. that this was the only one within several years past. Upon examination of the measuring chamber of this rotary meter we found the piston had so worn as to permit a thin film of deposit to form on the underside of the top plate, so that the effect was to diminish the height of the chamber and therefore

the volume per revolution. After removing this film with acid, the meter was restored to an accuracy of 99 per cent., where before the acid bath it had been 110 per cent.

There are two types of dials in general use. The one is known as a round dial, where each digit is counted by the revolution of a hand. The number of digits varies according to the size of the meter. To avoid binding of the shafts for the higher digits, one firm employs hard-rubber bushings for the bearings. The other is known as the straight-reading type register, and consists of a set of rollers, one for each digit. The roller of the lowest digit is geared directly to the source of motion, while the others are operated by trippers on a countershaft. The vital point of a straight-reading register lies in the design of this countershaft and its trippers, because the trippers for the higher digits operate so seldom that unless some means is provided for preventing it, they become tightly corroded to the shaft, and in so doing the tripper shaft breaks when the trippers of the higher digits are brought into operation. There are two designs which are covered by patents, one providing for an intermittent motion of the countershaft and the other for a continuous motion. In the former, the first tripper is fastened to its shaft so that the shaft turns once for each revolution of the first digit roller. In the case of the latter, the tripper shaft is geared directly to the main spindle, so that it operates continuously with the source of motion. To prevent tampering with meters, we deem it necessary to seal the dials only. Tampering with the measuring chamber or train gear is hardly ever done, and is so easy to detect that the department considers it over-precautious to seal the main casing, especially in view of the fact that the meters are read once a month. The department now uses an aluminum seal which is exceedingly cheap.

Meters are purchased under specifications which are designed to admit of standard makes that will insure satisfactory performance as to wear, corrosion and accuracy. The specifications contain clauses fixing the maximum impedance on full flow, the limits of accuracy at various rates of flow, and the uniformity of the alloy in the gear train. It also provides for sealing facilities, guarantees as to wear and costs of repair parts; and a special design for the dial cover. The dial cap specified is shown in Fig. 21 and is designed to avoid the usual trouble of condensation which becomes so dense on the under side of the glass as to prevent reading the dial unless the seal is broken and the dial cap removed. The hinged glass cover opens to

FIG. 21. HINGED GLASS DIAL COVER.

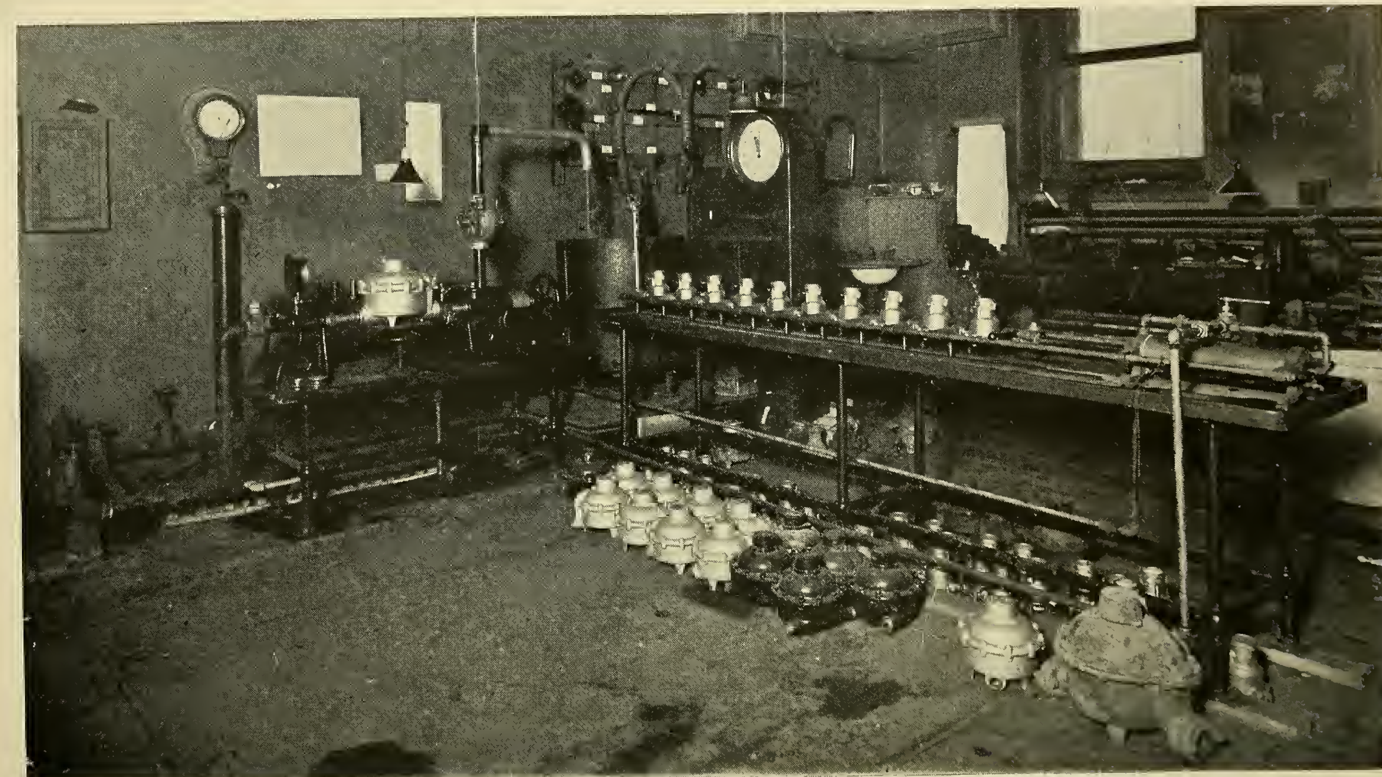


Fig. 22. Machine for Testing Small Meters, ten at a time.

an angle of 45 degrees, so that the cover will drop back into position after the moisture has been removed. In order to clean the glass it is not necessary with this arrangement to break the wire seal that passes through the screws. The hinged cover can be sealed in cases where it is considered necessary. This arrangement is intended to be used only with a straight-reading type of register; for it is evident that the hands of a round-reading dial could be so twisted as to be difficult of detection.

Each bidder under the specifications furnishes three sample meters of the smallest size, all of which are tested according to the specifications. One of the samples is submitted to an endurance run and tested for accuracy at fixed intervals of registration. The $\frac{5}{8}$-in. size are stopped at 250 000 cubic feet and the $\frac{3}{4}$-in. at 375 000. They are then examined and classified as to wear and accuracy. Recently disk meters were purchased under specifications for about half of what was formerly paid for rotary meters.

The policy of the department in installing meters is to place them in basements wherever possible. Whenever the basement is considered unsuitable for such reasons as inaccessibility for reading or repairing, exposure to frost, or a place of business not being adjacent to the building line, the meter is installed in a concrete box beneath the sidewalk or street, preferably the sidewalk. Meters 2 in. or smaller are installed with brass couplings and sufficient lead pipe to insure flexibility, for in replacing with another make, they are often of different lengths. Meters 3 in. and larger have flanged connections. In recent years it has been the practice of the department when installing meters 3 in. or larger to set a valve on the main line about one foot from the outlet of the meter and insert between this valve and the meter a 1-in. opening for testing the meter in its service position. In removing a large meter that has been in place for a few years, great difficulty is usually experienced in loosening the flanged joint. To break these joints quickly and not disturb the piping, a piece of apparatus has been designed; it consists of a channel beam supported by two posts so that by operating the two draw screws simultaneously a shearing force of 10 000 lb. can be applied to each joint. From a test, it appears that 120 lb. per inch of joint surface is amply sufficient. On this basis a force of about 8 000 lb. per joint will loosen a 6-in. meter, the largest size in general service. In connection with the work of removing and installing large meters, the department has in operation

a one and a half ton truck equipped with a chain block and trolley so that one man can handle a meter weighing half a ton. The 4-in. I-beam on which the trolley operates is supported by a framework of $2\frac{1}{4}$-in. T-bar and extends the entire length and 30 in. over the rear of the body.

It is the intention of the department to test meters at about certain intervals of registration. These intervals are selected where it is supposed the wear in service will most affect the accuracy. The scheme includes a time limit in which the meter must be tested at least once, even though the registration has not reached the first interval. This time limit is necessary because of the corrosion in meters that have only a small circulation of water. All sizes of meters are tested in the testing department on a Mueller meter testing machine equipped with auxiliary apparatus for testing large meters. It is equipped with a multiple cock so that meters can be tested for accuracy on various rates of flow. In testing on rates of flow greater than $\frac{3}{10}$ cu. ft. per minute, a quantity of 10 ft. on the dial is weighed in the tank by the automatic recording scale. The accuracy in per cent. when the dial of meter records 10 cu. ft. is then represented by the result of dividing 625 by the number of pounds in the tank. The operator is provided with a diagram, so that, knowing the weight of water in the tank, he can read therefrom the accuracy in per cent. In order to save time when testing on streams $\frac{3}{10}$ of a cu. ft. per minute or smaller, only 1 cu. ft. is recorded on the dial. The long machine shown in Fig. 22 is designed to test small meters only, but will test as many as ten at a time. They are arranged in series and held in place by hydraulic pressure in the cylinder at the inlet end of the machine. On this machine a man can easily test meters at the rate of 90 a day, as compared with about 15 a day on the machine formerly used. In testing 3-, 4-, and 6-in. meters on large rates of flow, the water is measured in a calibrated tank holding 50 cu. ft. It is 30 in. in diameter, so that each quarter inch of height represents one tenth of a cubic foot. The tank is calibrated only in the vicinity of 10 and 50 cu. ft., and the water level is read by means of glass tubes and scales. In testing by quantities of 100 cu. ft., each $\frac{1}{4}$-in. calibration represents $\frac{1}{10}$ of one per cent.

Before replacing 3-, 4-, and 6-in. meters they are tested in service by connecting a test meter to the 1-in. valve for that purpose. The operator is provided with a stop watch, so that he can regulate the rates of flow to correspond with the standard

shop test as shown in the chart. When such a meter in service shows an error of about 10 per cent. or less on the smaller flows, it is regeared to register accurately. When in error more than 10 per cent. it is replaced and repaired in the shop by refitting the piston chamber. For repairing and refitting meters a machine shop is now being equipped with such machines as a lathe, pipe machine, drill-press, grinder, shaper, and a drilling and milling machine.

In concluding, it might be mentioned that within the past year and a half the system of operation in the meter department has been changed with the view of handling its work more thoroughly and efficiently. In the system now used, the department replaces defective meters smaller than 3 in. so as to repair and test them in the shop, after which they are placed in stock ready for service. Also the system of records now in use results in more thorough work as it keeps a check on each man's work. This system is in contrast to the one it has replaced, where meters were repaired in place. The old system proved very unreliable and inefficient. In addition to the present value of the record system, its greatest value is in the future use of the data to determine therefrom the maintenance cost and accuracy in service of the various types and makes of meters. Since this system has been in operation about 80 per cent. of the 7 000 meters in service on July, 1911, have been repaired; about 60 tested, and over 14 per cent. condemned and replaced with new ones. There are 7 370 meters now in service, which is about 7 per cent. of the total number of service connections. The revenue from these metered connections in the past has amounted to about 40 per cent. of the total revenue of the water department.

[NOTE. — Discussion of this paper is invited, to be received by Joseph W. Peters, Secretary, 3817 Olive Street, St. Louis, Mo., by January 15, 1914, for publication in a subsequent number of the JOURNAL.]

ATMOSPHERIC CONDITIONS IN SALT LAKE VALLEY REGARDING FOG AND SMOKE.

By Alfred H. Thiessen.

[Read before the Utah Society of Engineers, September 17, 1913.]

The observations on smoke haze and fog in Salt Lake City have been tabulated since 1891. Unless one studies and observes the phenomena of smoke, haze and fog very carefully he will oftentimes not distinguish one from the other.

Haze is generally supposed to consist of minute dust particles suspended in the atmosphere. I say generally, because some have advanced the theory that haze consists of condensed water vapor on dust near the earth's surface, but as haze is very prevalent in autumn, when relative humidity is quite low, it does not seem probable that condensation can take place on such a large scale. Haze exists in the upper as well as in the lower layers of the atmosphere, but when in the upper layers it consists of minute ice particles, and resembles a cirrus cloud, or it is composed of dust from meteors or from volcanoes. The haze near the earth's surface is probably caused by the dust of the earth being blown about. Haze is prevalent in autumn; the drying leaves at that time probably add to the source of dust.

Smoke, as we all know, is the product of the chimneys. It is composed of the unburnt products of coal mixed with some gases, among which are water vapor, carbon dioxide and sulphur dioxide.

Clouds and fogs are formed by exactly the same processes, the cloud being an elevated fog and the fog being a low cloud. When air becomes saturated with moisture, some of that moisture condenses and forms cloud or fog.

We distinguish between light haze, smoke or fog. If smoke or fog obscures an object one thousand feet away, it is called dense. Otherwise it is light.

I believe that the manner in which fog or cloud is formed will throw some light on the smoke and fog conditions of Salt Lake City, and will therefore give it in some detail. It is usually said that fog or cloud is formed when the air becomes saturated or supersaturated; but this is not the whole story. To carry

the explanation further we usually go back to the basic work of John Aiken.

This experimenter was led to a line of inquiry which is very interesting to the meteorologist. He noticed that water never froze unless it was cooled to 32 degrees and in contact with some other ice particles. Also that water did not boil unless there was a free surface. If the heated water were covered with a layer of oil it may be far above 212 degrees without boiling. Reasoning from this it occurred to him that steam would not condense unless there was a free surface on which to condense. The sides of the vessel containing the steam would act as a free surface, and steam condenses readily on them. The experiments showed that condensation in the form of cloud took place very readily when the air contained dust, but that no cloudy condensation took place when the air was filtered so as to be free from dust.

Cloud is formed by the cooling which air undergoes when expanding. It is cooled below the dew point and condenses on minute solid particles.

Fog is formed by the cooling of air below its dew point, but the cooling is brought about by radiation or by the transportation of air from a warmer to a colder region.

If no dust existed upon which the moisture could condense the condition would be very different from that which we know. The moisture would condense on all exposed objects. Trees, houses, and so forth would be dripping with moisture. Our clothes would soon become saturated and umbrellas would be useless. Even rain coats would not avail much as the moisture would condense on one's face and flow inside his collar. And this has actually been observed in cases where the air was practically free from dust and at the same time moist.

The records of the United States Weather Bureau office at Salt Lake City show a much greater per cent. of sunshine in summer than in winter. In summer it reaches as high as 83 per cent. in July and falls as low as 43 per cent. in December and January. Likewise cloudy and rainy days are more prevalent in winter than in summer, and humidity follows the same general characteristics, the greater relative humidity occurring in winter and the least in summer.

A tabulation of the number of foggy and smoky days since the station was established shows that the greater number occur in November, December, January and February. A period from April to September inclusive is practically without fog or smoke as far as the records show.

Analyzing the records for the past twenty years we find an appreciable greater number of foggy days in the last decade.

It seems, then, that with the growth of the city the foggy days have kept step with it. As smoke gives an abundant number of particles on which the water vapor in the atmosphere can condense, it is logical to assume that in any city the fogginess will increase as the consumption of coal increases. The condensation of water vapor also facilitates the radiation of heat at night and thus aids the formation of fog. The following table shows how fogs have increased with the size of the city of London.

Year.	Annual Number of Foggy Days.
1871–1875	50.8
1876–1880	58.4
1881–1885	62.2
1886–1890	74.2

The hazing effect of water vapor in the air is not due to simply its presence there, but its presence in the company with dust particles. Dust particles seem to have the property of making water vapor condense upon them even when the air is not saturated, but of course the effect is greater as saturation increases, and is proportional to the relative humidity.

The amount of dust and consequently the amount of fogs depend also upon the direction and velocity of the wind. It has been frequently observed that a strong northerly wind will clear the city of fog very quickly. But a wind of the same strength from the south will not have the same effect. This is because the southerly wind must work against gravity in blowing up against the benches, while a northerly wind works with gravity.

Fog is dissipated by the sun. This being so, one can see that a fog will last longer in a smoky atmosphere than in a clear atmosphere. That is, fogs, under the same condition in a city and country will be dissipated more quickly in the country than in the city. There is still another difference between country and city fogs. The country fog particle is made up very much the same as a cloudy particle which has a tendency to rain itself out of existence, but a city fog is persistent and has little tendency to fall.

In conclusion, then, it may be said that city fogs increase as the city increases.

This is because of the greater amount of dust particles

thrown into the air by combustion and other means, thus giving water vapor a surface upon which to condense.

That fogs persist in a city more than in the country is due to their formation, and to the presence of smoke which does not allow the sun to evaporate them.

The number of the cloudy days has a direct effect not upon the number of fogs but upon their persisting after sunrise, allowing the fog to persist much longer than if it were exposed to the sun's rays.

[NOTE. — Discussion of this paper is invited, to be received by Joseph W. Peters, Secretary, 3817 Olive Street, St. Louis, Mo., by January 15, 1914, for publication in a subsequent number of the JOURNAL.]

POSSIBILITIES OF REDUCING THE SMOKE PRODUCTION IN SALT LAKE CITY.

By O. W. Ott, Member of the Utah Society of Engineers.

[Read before the Society, September 19, 1913.]

Various estimates have been made in eastern states as to the financial loss due to the smoke nuisance, and figures ranging from $8 to $12 per capita have been given to cover this annual loss. When the loss in the homes, retail and wholesale stores, hotels and other buildings, the losses to manufacturers, and loss due to effect on the health of persons, animals and plants are considered, it can be seen that these figures are easily attained. This paper deals entirely with smoke produced during the combustion of fuel.

The combustion of fuel consists of the oxidation of the various combustible elements in the fuel, or, in other words, the chemical combination of these elements with the oxygen of the air. If this oxidation is complete the products of combustion are principally carbon dioxide and water vapor with a small percentage of sulphur dioxide, and contain no opaque substances. In order to get complete combustion it is necessary that the oxygen of the air have free access to every particle of fuel, and that the temperature be maintained high enough to insure chemical combination. To obtain these conditions is the fundamental problem of combustion; and the secondary problem is to avoid passing an unnecessary amount of air through the fuel, because such surplus air has to be heated to the temperature of the escaping products of combustion, and the heat thus used is entirely wasted. For the proper combustion of coal, then, three elements or conditions are necessary. First, a sufficient temperature must be maintained to obtain proper ignition of the gases; second, the proper quantity of air must be supplied; third, the air and fuel must be properly mixed. When these conditions are all obtained it is a very simple matter to burn any kind of fuel, liquid or solid, without producing smoke. Taking these points up in order:

Sufficient temperature for proper ignition can best be obtained by proper furnace conditions. That is, the furnace construction and operation must be such as to conserve the incandescence of the fire and effectively use it in igniting the

volatile gases as they are given off by the fuel. In ordinary boiler installations this point is perhaps the one most generally at fault. Grates are placed too close to the boiler shells or flues, so that the gases, on being released from the coal, immediately come into contact with surfaces which are anywhere from 1 000 degrees to 1 500 degrees colder than the bed of fuel which they have left. On furnaces of this type the proper use of baffle walls, tiling and brick arches will help very materially, as will also the use of steam or air jets to direct the released gases back against the fuel bed where the temperature is sufficient for proper ignition. The lack of sufficient temperature for ignition may be due to other causes than poor boiler setting. Holes in the fire bed may allow an excess of cold air sufficient to greatly reduce the temperature of the fire. Such holes may occur with stoker-fired boilers as well as with hand-fired boilers. With the chain grate and step-down stokers the fire may be dropped and the grates bared for a considerable distance back from the end of the travel of the coal. With underfeed stokers oftentimes a whole section of tuyères will be uncovered.

The next point in order is the proper quantity of air. There are so many factors which control this that it is impossible to do more than mention the vital ones. The first in order of importance is probably draft or fan air supply. The air supply may be furnished entirely by the draft due to the chimney or induced fan, or by a combination of chimney and pressure fan, or of induced fan and pressure fan. The thickness of the fire carried and the amount of coal to be burned vary so much in different installations and at different times in the same installation that it is a difficult matter to regulate the air supply. In most plants a given size chimney is constructed and expected to take care of all the variations necessary for the proper air supply. It is unreasonable to expect to obtain economical and satisfactory operation under these conditions because the intermittent feeding of fuel and removal of ashes necessitate suitable variations in the air supply. It is true that with the single shovelful method of hand firing the conditions are more nearly uniform than with other methods usually employed, but in any case, the opening of the fire door reduces the ability of the chimney to pull air through the grates and at the same time introduces a considerable quantity of cold air at a point above the fire. A steam jet discharging through the front wall and immediately above the door, which will operate whenever the door is opened, will aid considerably in improving conditions by

directing the incoming air down against the fire where it will have the least cooling effect, and by mixing the gases immediately distilled from the fresh coal with this air and directing the mixture back against the fire bed.

In overfeed types of stokers careful regulation of the chimney damper in accordance with feed of coal will aid considerably in maintaining uniform fire conditions, provided, of course, that the stack has sufficient capacity. In the underfeed type of stoker, varying the speed of the fan is the proper solution. This can best be done by means of a governor which is controlled by the demand for steam made upon the boilers. It must not be lost sight of, however, that the ratio of the fan speed to the coal supplied is by no means a fixed relation. This is due to the fact that as the stoker is crowded the thickness of the fuel bed is rapidly increased and thus the necessary pressure required to force the air through the same greatly increased.

The introduction of air through hollow arches, hollow stay bolts, or openings other than the fire door, has a good effect in many instances, but unless the supply of air thus admitted can be controlled according to the rate at which the coal is burned, it is liable to occasion loss of efficiency due to excessive cooling of the gases during periods when the extra air supply is not required for combustion.

The next point in order is the proper mixing of the gases. In order to obtain the full benefit from proper mixing both as to economy and smoke abatement, the mixing of the distilled gases and the air supply must be done preceding the direct contact with the flues or boiler shells. With coal containing a high percentage of volatile matter this can best be done in brick combustion chambers. This combustion chamber effect can be most easily and economically obtained by the use of Dutch ovens. .Where Dutch ovens are not permissible, brick arches and baffle walls and tiling can be used. Checker brick work can often be used to divert or interrupt the passage of the gases, and thus bring about a better mixing. This is absolutely essential in oil-burner work. Another method of obtaining proper mixing is inherent in the down-draft grate and the underfeed stoker. In the first of these the air is compelled to mix with the distilled gases on their way through the fire. In the second, the high pressure required to force the air through the fire produces a very good mixing close to the surface of the fire. With the most common type of boiler setting where no combustion chamber effect can be obtained, either by Dutch oven setting or

baffle brick, a steam jet will often give considerable assistance in obtaining proper mixing simply through its disturbing action in interrupting the normal passage of the gases.

Taking the various smoke offenders up in order, the problem of the large plants becomes essentially a matter of stokers with proper boiler setting, proper draft conditions obtained by damper regulation or control of fan speed. Peak loads must be taken care of automatically by varying the air supply, either by damper regulation or fan speed. Where a plant has overfeed stokers it is up to the chimney. If the chimney is not large enough, provision must be made for some other method of taking care of the increased air supply required by the peak loads, such as pressure blowers.

Another very serious problem in the large plants is the matter of starting up in the mornings where fires are banked the previous night. Where plants use steam engines to drive the fan and stokers, and these engines will not operate on less than 30 to 60 lb. pressure, there is a period from one-half to one hour when the air supply is practically cut off and the smoke will be extremely serious. The remedy for this is an auxiliary motor drive for the fan and stokers for use during the starting up period.

On overfeed type stokers this starting-up proposition is not so serious, but still the draft is greatly impaired by the chimney having cooled down, and thus considerable care must be used in starting up slowly or else much smoke will be emitted.

The problem of the small plants is much more serious, due in great part to the fact that it is not the rule to have a fireman in constant attendance; there are numerous instances where one man takes care of three, or four, or even six, boiler plants, and of course has to resort to very heavy firing at infrequent intervals. The remedy is not easy. If the plant owners could be convinced that more money spent for labor would mean a considerable saving in coal, a large step would be taken. However, minor changes in boiler setting, the use of steam jets or auxiliary blowers and a better schedule for firemen will effect much improvement. If schedules could be arranged so that one fireman would not have to start all of his boilers at practically the same time, so that he would devote more time to each boiler and build the fires up more slowly, the worst smoking period of the day would be greatly improved. The problem of homes and apartment buildings is as serious as that of the smaller downtown plants. The period of starting up fires in the morning is

the most productive of smoke and is the one in which the most improvement can be made. If the furnace tenders could be made to realize that all of the conditions required for good combustion are upset at this period, and further that considerable coal is wasted, perhaps some advance could be made. The remedy is the expenditure of more time in starting up, together with the use of kindling. In the morning, the fire remaining from the previous night is at a very low ebb; the chimney is cold; and the draft is practically nil. When the furnace tender dumps three or four big shovelfuls of coal on top of the remaining fire he simply makes a distillery of his furnace, and great quantities of smoke and unconsumed gases pass up the chimney until such time as the draft has improved and the fire picked up to a sufficient point to ignite them. The use of kindling to warm the chimney and thus get the draft started, and the feeding of lump coal in small quantities over a period of one half to three quarters of an hour would make a wonderful change in the smoke conditions in this city and still permit the use of bituminous coal for fuel purposes.

The next and final problem is that of locomotives. No one who has ever taken a trip into the railroad section of the town but has been impressed with the immense amount of smoke turned loose by the switch engines. This same problem existed in Chicago, and there great strides are being made in the reduction of this nuisance. The application of brick arches and steam jets with special auxiliary blower nozzles in the smoke box has done a great deal in reducing this smoke and at the same time has increased the evaporation obtained from the fuel, and consequently made a considerable saving in the coal bill. The great problem here, of course, is the alternate heavy demand for steam and sudden throwing off of all the load on the boiler. It must be remembered also that at the same time the load is cut off, the draft is cut off. This of course is inherent with the locomotive. Auxiliary draft supplied by means of a smoke box blower during period of inaction and the admission of air above the fire by the steam jets have helped a good deal to hold down the smoke during these periods of inaction. As mentioned before, the steam jets also assist by better mixing and by driving the gases back against the fire.

The last point to be taken up is that of the necessity of a proper smoke ordinance, together with its enforcement. Such is unfortunately necessary as a great many people can be appealed to through no other means than their pocketbooks. In

connection with such ordinances, examples of which can easily be obtained from the big cities, such as Cleveland, Chicago and St. Louis, a proper check should be kept on the smoke offenders and lists of the offending plants published from time to time in the newspapers, and proper warning notices sent to the owners of these plants.

The first and most important step is to appoint three or four smoke inspectors, at a salary of $40 or $50 per month each, who would devote their entire time to making observations on all the principal stacks. Ringleman smoke charts should be used, and tabulations should be made of the time of day, density and duration of emission of smoke from the various stacks. The publication of these data, together with a little coöperation from the legal department after the notices have reached the no-effect stage, would have a most salutary effect. Coöperation should be the watchword, and the best way to stimulate the spirit of coöperation is first of all to educate the people so that they may know what the present status is and what improvements are and can be made; and then to penalize the few who refuse to coöperate.

[NOTE. — Discussion of this paper is invited, to be received by Joseph W. Peters, Secretary, 3817 Olive Street, St. Louis, Mo., by January 15, 1914, for publication in a subsequent number of the JOURNAL.]

PAVING PROGRESS IN GREATER BOSTON.

By James H. Sullivan, Member of the Boston Society of Civil Engineers.

[Read before the Society, April 16, 1913.]

In the early days in this country, road construction or street paving did not receive much attention, but it is evident that some of the old residents must have experienced some difficulty, as there is a record that in the year 1800 a bill was introduced into Congress for the construction of national turnpikes. Transportation facilities were crude; communication with the interior was a matter of days and often weeks. However, we read that in the year 1830 several of the states granted charters to groups of individuals for the construction and operation of steam railroads, and in 1835 there were three steam railroads operating out of Boston; one to Providence, one to Worcester and one to Lowell. This was the beginning, and thereafter the growth and development of railroads was prodigious. Financial and engineering talent and skill were employed in railroad development, but it apparently did not appeal to the authorities that the same elements were essential for the construction of streets and highways as for the railroads.

Private interests developed the railroads and in so doing developed the country, but private interests never entered into the development of highways to any extent; consequently there was no marked improvement in their character for many years. There were instances, however, where individuals undertook the maintenance of roads, collecting a toll from those using them, but the amount collected could not have been large, as the roads never got beyond the category of the country road and eventually were taken over by the counties. From the inception of the railroad the aim was the scientific and economic building and maintaining of everything pertaining to the system, experimenting and investigating in order that all practical knowledge possible might be gained and applied to the work. Such was not the case with the streets or highways. There was lack of knowledge, lack of skill in the construction of a road or in the proper maintenance of what did exist.

This was the condition in which the country drifted along for years; no marked improvement, although the cities and towns

were increasing and developing in all directions. The first attempt at paving we note, in the early fifties, was the use of cobblestones, or round field stones and stones collected at the beaches. In special cases where particular work was to be done the kidney stones were used. These kidney stones were more uniform in size, flat, oval in shape and obtained only on the coast of Nova Scotia.

Notwithstanding the backward condition and apparent lack of suitable material, there were individuals who had been giving the paving question some thought. As early as 1853 the inventive genius, the man with the patent, made his entry and did succeed in inducing the authorities in Boston to lay an iron block pavement in Court Street, between Washington Street and the Court House, at a cost of $10 per sq. yd., and in Washington Street, between Court Street and School Street, at a cost of $6 per sq. yd. This block was known as the "Terry heavy" and the "Terry light" block. The heavy block measured 12 in. square by 5½ in. deep and weighed 36 lb.; the light block measured 14 in. square by 4½ in. deep and weighed 31 lb. This pavement gave satisfaction for a short time and after a couple of years went to pieces and had to be removed from the street. About this time another iron block, called the "cellular" iron block, was laid by private parties as an experiment, but never got beyond the experiment. About this time the Nicholson wood block, patented in 1848, made its appearance. The Nicholson block, coated with tar, was laid on boards. Later came the Warren and the Boston wood block schemes. Both of these makes of wood block were laid in gravel, with gravel joints, the gravel being washed into the joints with water from a hose or watering-pot. These pavements were used considerably for a number of years and eventually all suffered the same fate; they broomed and rutted badly and became very unsanitary and dangerous, and after a time were removed from the street.

The Belgium block, a trap-rock block, 4 in. square by 7 in. deep, shipped from the Hudson River, was first used in 1863; and later what was called a small granite block, 3 to 4 in. wide, 6 to 7 in. long and 7 in. deep, was used extensively. Work was confined to these granite or wood block pavements until 1877, at which time we note the record of the first asphalt pavement, there being 15 000 sq. yd. of Trinidad and Grahamite asphalt laid, replacing the old wood blocks. Asphalt grew in favor, and more or less of it was laid each year.

The use of untreated wood blocks having been abandoned, there was hardly any choice in the selection of paving materials; it was either asphalt or granite blocks laid on a gravel base, a condition that existed until 1891. It is evident therefore that there was no real development in paving materials or in the use of such materials as were available.

In 1891 the first real permanent pavement was laid. It was considered as the last word in a pavement for general traffic, and described as a substantial, durable pavement that would wear for many years, and was laid on streets where the traffic was intense and heavy. It was constructed with large granite blocks, with pitch and pebble joints, on a 6-in. Portland cement concrete base. During the next ten years this pavement was much in demand and was laid extensively throughout the business sections. In the meantime Trinidad Lake and Sicilian asphalts were competing quite vigorously, and considerable areas were laid in residential sections. In 1900 the first treated wood block was laid. This block, a long-leaf yellow pine with creo-resinate treatment, was laid in a number of streets, and although many were skeptical as to the life of the pavement, it is still giving excellent service and is apparently good for many years more. The fact of the matter is, the treated wood block pavement is suitable for any traffic, its use being restricted only by the grade of the streets.

Other pavements have also been used, namely, bitulithic and vitrified bricks, but from experience gained in the past there are but two pavements, granite blocks and wood blocks, that can be said to be suitable for general traffic from the standpoint of economy and durability. The maintenance on a granite-block street or a wood-block street due to the wear and tear of the teaming traffic is negligible. It is a fact that no expenditures were necessary for the maintenance of the wood block laid in 1900 and 1901 during the guaranty period, which expired during the past two years, nor since. Repairs have been necessary on one or two streets, due to extraneous sources. While these two forms of pavement are very similar in their wearing qualities, they are very dissimilar (in fact, one is the antithesis of the other) in that one point which is contributing so much to the undermining of the health of the people, — and that is, noise. Previous to the laying of wood blocks our people seemed satisfied with the granite-block pavement as laid since 1891 in the business and office building sections, and no word of protest was registered against the noise arising from the traffic. But since

the advent of the wood block such is not the case. To such an extent has the noise affected the nerves of the people that instances have been cited where business men have been compelled to take protracted vacations. Petitions praying for the substitution of wood in streets where the granite blocks were in first-class condition and in no need of repair have been accompanied with offers from the owners and occupants to pay for the cost of the wood-block pavement. Substitutions of this character have been made at the expense of the abutters, they stating that the rental value of their property will appreciate beyond their proportionate cost of the wood-block pavement. Negotiations of a similar character are in progress which will probably develop this season in the office building sections. Thus it will be seen that granite blocks on a concrete base where noise is not a factor is the economical pavement. On the other hand, where the noise has to be taken into consideration and the traffic is considerable, a wood block is the accepted form of pavement. As regards the item of cost, there is no material difference, the price per square yard being about the same for either kind of pavement:

Specifications.

The success of any pavement depends on a good substantial foundation; and the manner in which the sub-grade is prepared to receive the foundation has a very decided bearing in the subsequent life of the pavement.

Preparing Site. — The grading and preparing the roadbed for the superstructure will include all excavating and filling necessary to bring the sub-grade to a surface which will conform to and be parallel to the finished pavement. It will be made solid and of even surface by use of a heavy steam roller, and places not accessible to a roller are to be tamped with hand rammers. Where any substance is met with which is not suitable it is to be removed and proper filling substituted.

The portion of the specifications, prescribing the use of a roller to compress the sub-grade, is hardly applicable to our city streets, where the car-tracks, manholes and gate-frames and other surface connections to the underground structures which abound in our streets are considered, and it will become apparent that a steam roller would be as fit as the proverbial bull in the china shop. It will be found, however, that the sub-grade of our streets is fairly well compacted, and if care is used in removing the surplus it will be found that hand tamping will give the desired results. The places that should have close attention are

the trenches which have been opened and backfilled by the corporations who have made repairs to their underground work in anticipation of the street construction.

On the sub-grade thus prepared a concrete foundation 6 in. thick is placed, composed of one part Portland cement, three parts screened coarse, sharp sand, and seven parts crushed stone. With the proper materials there is but one way to make a proper cement mixture. The sand and cement must be thoroughly mixed dry until the mass is completely blended and free from streaks before any water is added, otherwise it will produce a heterogeneous rather than a homogeneous mass and consequently very uncertain mortar. The mortar is then spread evenly over the stone previously wetted and the whole turned rapidly until each particle is entirely coated with cement, deposited in place and rammed until the mortar flushes to the top. Templets and other forms are set to line and grade and firmly secured so as not to get out of place before the concrete has set. In the making of concrete there are a few items that cause discussion at times during the progress of the work, namely, the stone furnished and the use of water. Specifications prescribe the maximum size of the stone to be used and also the minimum, the whole to be evenly graded between those sizes. Experience has shown that the tendency is to furnish a uniform size, generally the largest; consequently the aggregate will not be properly proportioned, and the concrete will contain a large percentage of voids. It is therefore very essential that the crushed stone should be graded as prescribed.

Paving contractors in this section have not grown to the use of mechanical mixers; therefore the board mix is the method still in use. When water is used in abundance the cement is washed through the mixture and runs off the board, which means that the cement does not adhere to the stone, the important ingredient being wasted; and furthermore where specifications call for a thorough ramming, it is evident that a wet mixture is not contemplated.

Granite Blocks. — The original granite-block specifications prescribed the size and cut of the blocks as follows: "Of the best Quincy or Cape Ann granite $3\frac{1}{2}$ to $4\frac{1}{2}$ in. wide, $7\frac{1}{2}$ to 8 in. deep and 9 to 14 in. long, averaging not less than $11\frac{1}{2}$ in.; the edges are to be shaped straight, forming right angles at their intersections both horizontally and vertically; the faces are to be straight split and free from bunches or depressions exceeding $\frac{1}{2}$ in., and are to be laid with close joint as possible." Blocks have been

furnished under this specification for about seventeen years, and the pavements have given satisfaction, there being but one objection, which is, the top of the block cobbles, or wears rounded, forming an uneven surface. If the last part of the specification is noted; to wit, "The faces are to be straight split and free from bunches or depressions exceeding $\frac{1}{2}$ in., and are to be laid with as close joint as possible," the reason for the wear may be accounted for. It is very apparent that joints one inch wide would be the rule and not the exception. These joints are filled with pitch and pebbles, but the filler is no protection to the edges of the blocks, and the joints being so wide the blocks are no protection to each other, therefore the constant impact of the calks of the horses' shoes knocks the edges off the blocks, and in the course of a couple of years the pavement in a busy street is worn round.

About five years ago blocks that had been under traffic for about fifteen years were examined to determine the wear. It was observed that the wear or loss from abrasion measured down the center of the block was very little, averaging about one-half inch, the greater loss being on the edges. It was deduced from these observations that the cobbled surface contributed largely to the noise, inasmuch as the tire of the wheel coming in contact with a succession of high points caused the racket so much complained of on granite-block paved streets. It was decided that, as the large blocks did not show any great loss in depth after such a length of service, a block of less depth but cut so as to be laid with a close joint would be just as serviceable, not so apt to cobble, thereby providing a smoother and less noisy pavement. The following specification was therefore adopted.

The blocks are to be smooth finished on the vertical sides and ends, the edges are to be sharp and straight, forming right angles at their intersections, both horizontally and vertically, and lay close with joints not to exceed one-quarter inch; the blocks are to be 8 in. to 12 in. long, 4 in. to $4\frac{1}{4}$ in. wide and 5 in. to $5\frac{1}{2}$ in. deep. This specification has been in operation about five years, the pavements laid are even and smooth riding, and no evidence of wearing round on the top has appeared. The cost of these special cut blocks is about the same as the large No. 1 block. There is less stock but more labor required in the cutting.

Many cities have adopted this special cut block, laying it up with a joint not to exceed three-eighths of an inch and using in

some places a pitch filler and in others a cement grout. In this city, a pitch filler is used entirely, cement grout filler not having been used for ten years or more. There is no question raised as to the virtue of a cement grout filler for granite block. A street paved with granite blocks and cement grout filler is without doubt surfaced with as permanent a structure as has ever been placed on a street, provided local conditions are such that the pavement is not likely to be disturbed.

In 1900 and 1901 the bulk of the pavement laid, and it was considerable, was laid with a cement grout filler. The pavements were laid in the business and office-building sections and it was not long before the newspapers had a new staff of correspondents telling the public what a frightful imposition it was to lay such a noisy, nerve-racking pavement in any street. This agitation subsided after a while, when other and more effective objections were submitted. In filling the joints the grout was swabbed about over the blocks to flush the joints to the top. In doing so more or less of the grout remained and caused a smooth surface which set, and afterwards became very smooth and glassy, so much so that the master teamsters protested vigorously. At first sand was used to overcome the difficulty, but to no purpose; and finally the men, stone-cutters and laborers that could be spared, were put at work cutting the cement, following the joints in the paving, in order that the horses might have better footing. This work was expensive and extended over several years and would have cost more were it not for the numerous street openings, which, by the way, are the most serious menace to any pavement. Our streets are so traversed with underground structures that it is hardly possible to find a location for another, and it is the openings made to get at these structures that make a monolithic pavement impracticable.

In one street in particular the water department found it necessary to relay a water main, and when they started to remove the pavement it would remind you of a quarry. Bull-points, sledges and stone hammers were the implements, and when they did get the blocks out a large percentage was waste. On repaving the trench a straight joint was made on each side, it being impossible to knock out the bats so as to break the joints without damaging a great many more blocks. This is but a sample of what occurred in the grouted streets, — great difficulty in removing the blocks, a loss of blocks by breakage and inability to remove the grout. These streets have been opened so frequently and repaired with pitch or gravel that it would be diffi-

cult, for one who did not know it, to state what the original paving was. These are the reasons why the grout paving area in Boston does not increase.

Wood. — The woods used generally throughout the country and found acceptable are, long-leaf yellow pine, Norway pine and tamarack, the long-leaf yellow pine having the lead in popularity.

The specifications of most cities prescribe that the wood to be treated shall be southern yellow pine, the blocks to be well manufactured, full size, saw butted, all square edges, free from all defects, such as checks, unsound, loose or hollow knots, knot holes, worm holes, through shakes and round shakes that show through the surface.

In yellow pine timber the annual rings shall average not less than eight to the inch and shall in no case be less than six to the inch, measured radially. The Boston specification calls for southern long-leaf yellow pine, not less than 80 per cent. of heart, of a texture permitting satisfactory treatment, and is to be subject to inspection at the works, in the stick, before being sawed into blocks. No second growth timber is to be allowed. The blocks are to be well manufactured, truly rectangular and of uniform dimensions. The requiring of 80 per cent. heart wood is a bone of contention inasmuch as it is difficult at times to get all heart wood, and furthermore commercial long-leaf yellow pine is seldom free from the rapid growth and loblolly pine. The difference between the long-leaf and the loblolly is in the sapwood area, that of the long-leaf being so narrow that it might be neglected, while in the loblolly or second growth it is often very wide. It is claimed, however, by creosoting engineers and also by the United States Agriculture Department, that when effective seasoning can be secured before creosoting the prohibition of sapwood is needless. Notwithstanding these opinions it is better to maintain the standard rather than let the bars down and allow opportunity for further inferior material, as it is asserted by other authorities that the short-leafed, loblolly and second-growth timber is inferior in strength and subject to rapid decay.

Treatment. — The blocks are to be thoroughly treated and impregnated with an antiseptic and waterproofing oil of the character hereinafter described. The method of treatment will be such as conforms to the best and most advanced knowledge of the art, the purpose of the city being to allow contractors to manufacture block by following any preferred detail and by the

use of any process which may be properly adapted to secure the results demanded, namely, that all parts of each individual block shall be thoroughly impregnated with the preservative, which will require not less than 20 lb. per cu. ft. of wood, shall result in a block which shall not be split or warped, shall have a specific gravity greater than that of water.

The antiseptic and waterproofing oil is to have a specific gravity of not less than 1.12 at 48 degrees fahr. When distilled in a retort, with the thermometer suspended not less than one inch above the oil, it is to lose not more than 35 per cent. up to 315 degrees cent. and not more than 50 per cent. up to 370 degrees cent. The oil is to be free from adulteration; it is not to be mixed with or contain any foreign material.

After treatment the blocks are to show such waterproof qualities that, after being dried in an oven at a temperature of 100 degrees for a period of twenty-four hours, weighed, then immersed in clear water for a period of twenty-four hours and weighed, the gain in weight is not to be greater than 3 per cent.

The commissioner may have tests and examinations made at the contractor's works of the materials and blocks proposed to be used, and reject any or all of such materials and blocks as he may consider not to be in compliance with these specifications. The commissioner may appoint an inspector at the expense of the contractor, who shall inspect the lumber and other materials used in the manufacture of the blocks, and the treatment of the blocks; and he shall reject any of such materials and blocks as he may consider not to be in compliance with these specifications.

The method used to impregnate wood for paving purposes is by vacuum pressure. Closed cylinders, usually about 6 ft. in diameter and 100 ft. long, are used. The oil is injected into the wood, the amount varying from 16 to 20 lb. per cu. ft. This amount of oil seems to be considered by some engineers as unnecessary, but as pavements are wet a greater part of the time the impregnation should be complete in order that the waterproofing as well as the decay proofing should be thorough.

Upon the surface of the concrete foundation is to be spread a bed of cement mortar one-half inch in thickness. The mortar surface is to be composed of a slow-setting Portland cement and clean, sharp sand, free from pebbles over one-quarter inch in diameter, and mixed in the proportions of one part cement to four parts sand. This mortar top is to be thoroughly rammed into place with concrete rammers until all the unevenness in

the concrete is taken up, and is then to be "struck" to a true surface exactly parallel to the top of the finished pavement.

On this mortar surface, spread and smoothed as above to the proper crown and grade, the blocks are to be laid with the grain vertical and at such an angle with the curb as the commissioner may direct. They are to be laid in parallel courses with as tight joints as possible, each block being firmly imbedded in the mortar bed so as to form a true and even surface.

The joints are then to be filled with cement grout composed of two parts of clean sand and one part of Portland cement mixed to a perfect liquid form, and the surface of the block is to be slushed with the same and the joints swept until they are completely filled; expansion joints, filled with a paving cement of proper consistency, are to be made next the edgestones. The surface is then to be covered with one-half inch of screened sand.

The specifications for mortar bed and grout joints will be changed in the specifications hereafter, and a one-inch sand bed substituted, the joints to be filled with heated sand. The latter is the method adopted and in use in several cities during the past two years, the results obtained being more satisfactory than the use of cement.

Asphalt.

When asphalt pavements were first introduced, street officials were not very well acquainted with the constituent parts that went to make up the mixture, and it might be said the asphalt contractors were in somewhat the same position, and what we have to-day is the result of experiment and experience carried on for about forty years.

The first asphalts were laid in one course, $2\frac{1}{2}$ in. to 3 in. thick, although some pavement was laid in two courses, the first, or bottom course $\frac{1}{2}$ in. thick, sometimes called the cushion course. This pavement became very wavy, owing to the thickness of the asphalt, and experiments were made with broken stone coated with asphalt, for a bottom course, which proved very satisfactory. It was called the "binder" course, and thereafter the asphalt pavement was known as binder and top, the depth of each course generally being one and one-half inches binder and one and one-half inches wearing surface. The representation that the binder course prevents the waving or creeping of an asphalt pavement is not sustained by actual conditions. The condition of the concrete base, whether the surface is rough or

smooth, is one of the factors; also whether the base is moist, due to capillarity in damp ground.

When the experiments with binder were first made it is very probable that the surface of the concrete was very rough and gave opportunity for the small stones composing the binder to wedge in and thereby form a bond which did prevent movement. But that is not the experience to-day; the binder course is used, yet the waving continues. It is evident that a base with a fairly even surface offers no opportunity for bond with the binder; our asphalt surfaces exhibit the creeps even to-day. Again, when a concrete base is moist or damp, owing to a wet sub-soil, there is no bond, no connection whatever, and if the bottom of the binder course were examined it would be found that the moisture was rotting the pavement.

And yet to-day, after forty years' experience, can it be said that asphalt pavements have arrived at the final height of development? The life of the pavement is uncertain. On residential streets it has given good service, but where the traffic is continuous or heavy its life will not exceed ten years. It has one disagreeable feature, and that is it goes to pieces and becomes very unsightly at a time when it is almost impossible to make repairs. In regard to the bitulithic pavements laid in our city the service has been very good. The maintenance guaranty being in effect, no expense was attached to the city for repairs. The contractors have kept the pavements up without any prompting on the part of the department officials. But now, as the guaranties are expiring, it is just possible that it may not be considered any more economical or desirable than the asphalts.

DISCUSSION.

Mr. Lewis M. Hastings. — There is one point about the specifications which Mr. Sullivan mentioned, and that is the desire to use an inferior quality of wood, properly treated. I do not believe in it. I have been reading a paper by the city engineer of Minneapolis. He said you can put it down for a fact that you cannot take poor wood and by any process of treating make it good wood. I think that is so. You cannot make bad wood lasting by filling it full of creosote oil. If your wood is poor, you cannot make it any better. For that reason I have considered that sap wood is very objectionable, and also the cheaper grades of pine. We all know what sap wood is on timber on a bridge, etc. When you get it underground I do not think there is much chance for it

to live, especially when it is so soft and punky as we have found it to be; so I think we ought to keep the quality of the wood up instead of letting it down.

Mr. Marvell. — I would like to ask Mr. Sullivan about the wear on a granite block.

Mr. Sullivan. — It should last about fifteen years.

Mr. Fernald. — I would like to ask Mr. Sullivan how they propose to overcome the swellings or blisters which appear on the wood paving. I notice in front of the Boston *Globe* there is at present more or less blistering or rising, due, I take it, to the dampness of the pavement there, which looks rather poor and uneven at the present time.

Mr. Sullivan. — How we shall overcome that I do not know. We will have to temporize with it. It is one of the bad features of the wood block paving. The wood does absorb some moisture even after treatment. There is one thing which I think affects that somewhat seriously, and that is the cement grout joint between the wood blocks. I think that is largely the cause of the swelling, in addition to what moisture the wood block does absorb. I think we will get rid of that hereafter by using an ordinary sand joint without any cement.

Pavements in Brookline.

Mr. Alexis H. French. — Brookline, as you all know, is a small town with an area of about 4 363 acres, but a rapidly growing population of about 30 000, and hitherto has done comparatively little in the way of permanent pavement. Up to within a few years our street department has depended upon water-bound macadam, and more recently upon macadam with a bituminous binder, but the advent of the automobile has demonstrated the absolute necessity of a wearing surface of a quality better than either of those materials. The first effort in the way of a pavement was made with brick laid on a 6-in. concrete base with a $1\frac{1}{2}$-in. sand cushion and a cement grout filler. Metropolitan brick have been thus far used, and an expansion joint of pitch placed next to the curb and at intervals of about 50 ft., transversely. The Portland cement grout filler is a 1 to 2 mixture, and it should be said here that its preparation and application require the utmost care to secure the best results, and of all the steps in the process, the failure to do this work in the best way is sure to lead to disappointment.

The brick pavement has been fairly satisfactory where the

travel is not too severe, as it does away with a muddy street surface, avoids the necessity for crosswalks, is always in condition to use even in wet weather, and is easily kept free from dust. The objections to it are its noisiness, its tendency to wear in pockets by starting with a brick softer than the average as a nucleus, and a chipping of the brick at the joints so that after a few years they have a cobblestone appearance when the travel is concentrated, as it sometimes is between the curb and the street car track, and sometimes along the line of maximum travel in fairly wide streets.

Under present conditions its cost is about $2.85 per square yard, about $1.10 of which represents the cost of sub-grading and the concrete base and $1.75 the cost per square yard of the pavement proper. With average conditions the life of the pavement can be said to be from twelve to fifteen years, and even then parts of the work would not require relaying, from which it would appear that a cost of 15 cents per square yard per year would represent an outside estimate of upkeep. This upkeep is a very favorable one as compared with macadam, considering the many advantages of this type of pavement over macadam in its freedom from its annual charges for maintenance, freedom from mud, and the much smaller cost from laying dust.

As a detail of the construction I would like to call attention to the compressed concrete base with which some of you are familiar. After rolling the sub-grade, a layer of the mixture of No. 1 and No. 2 crushed stone is deposited on the sub-grade with a thickness of 4 in. after rolling. A 1 to 4 cement grout mixture is next applied until the voids are filled, when the surface is again lightly rolled so that it is even and smooth. The Simpson Brothers Corporation, who are doing much of our work, are using special appliances which do this work both well and economically. I think that concrete thus mixed is as strong, with a depth of 4 in., as a 6-in. layer laid by hand, and compressed by ramming, the larger depth being the one ordinarily used as a foundation for pavement.

Much economy comes in saving in handling, it being cheaper to place a bed of crushed stone than to handle the same material in the process of mixing and placing of concrete. I have seen compressed concrete cut into and satisfied myself that it is as good, if not better, than hand-mixed concrete. It is evident that broken stone must be free from dirt and other material which would interfere with the free flow of grout through the crushed stone. Given clean stone, the grout continues to flow into it until the soil below the stone becomes so impregnated from the grout that it

cannot escape in that direction, and it then rises in the mixture of broken stone to the surface.

The other pavement which we are now laying to a considerable extent has a wearing surface of fine grained and rather soft Southern New Hampshire granite about $4\frac{1}{2}$ in. thick, with a $1\frac{1}{2}$-in. sand cushion and a 4-in. compressed concrete base. The total thickness is 10 in. and the blocks are grouted with Portland cement filler. The resistance to wear of the grout and granite is such that they wear down evenly without being slippery. It has been used quite extensively in Worcester, and some that I have seen, which has been in use fifteen years on much traveled streets, was in perfect condition and free from objection. An expansion joint consisting of folded roofing paper placed next to the curbstone appears to be sufficient for the purpose. Considerable of this work has been done on Beacon and Harvard streets near Coolidge Corner, and on Boylston Street between Village Square and Cypress Street, also on Washington Street near Washington Square. Its cost has been about $3.25 per square yard.

Brick Pavements in Cambridge.

Mr. Lewis M. Hastings. — Cambridge has always been somewhat conservative in adopting new and untried pavements. For many years the only street surfacing used was gravel, some cracked stone, and field stone or granite blocks on a dirt or gravel base. In the western part of the city large banks of fairly good gravel were found and used in the early days, until they were exhausted. Then cracked field stone began to be used, and proved a far more durable and satisfactory material than the bank gravel, although more costly.

Some of the streets with the heaviest traffic — like Bridge Street in East Cambridge — were early paved with field stone or "cobble" paving.

A low-grade granite paving block soon made its appearance on the market, and quickly supplanted the intolerably rough and noisy field stone paving.

The granite block — modified somewhat in size and shape and greatly inproved in accuracy of cutting — has remained as the standard material for a durable pavement for streets carrying a heavy traffic.

With the natural increase in street traffic and the growing demand for better and smoother as well as more durable pavements, other types of street pavement have from time to time been adopted.

In an endeavor to get a smooth and noiseless pavement, in 1894 a part of Massachusetts Avenue near Harvard Square, containing about 5 315 sq. yd., was paved with sheet asphalt on a concrete base. While at first this pavement looked well, it did not prove durable, deterioration soon showing itself, rendering frequent repairs necessary, and it is now removed and the street paved with wood paving blocks. No asphalt pavement has since been laid in Cambridge.

In 1899 the question of trying vitrified brick as a paving material was considered. It was found that a great variety of opinions existed as to the merit of this material, — some claimed that it was expensive, short lived, and excessively noisy; others claimed that it made the best pavement in existence.

To learn more about the matter and get the experience of other cities, a committee of the City Council with the superintendent of streets and the city engineer visited a number of cities using this pavement, and also a number of the larger yards where the bricks were made.

While there is a common and probably well-founded objection in the minds of many to "junkets," as they are sometimes called, yet if these tours of observation can be conducted in a fairly intelligent and honest manner, I believe they serve a very useful purpose. In no other way can such reliable and first-hand information be obtained by the average member of a city council, and the experience and broadening of view gained in observing the progress and methods of other cities cannot but be helpful and instructive. Largely as a result of this investigation, the city of Cambridge has from time to time laid in streets where the conditions seemed favorable, pavements of vitrified bricks of various makes with generally satisfactory results.

The first street paved with brick was Prospect Street, leading from Central Square, Cambridge, to Union Square, Somerville. This was in 1899. This street gives some rather interesting data, as the entire roadway is only 33.33 ft. wide between curbs and contains a double street car track, which of course concentrates the traffic on the sides. The brick used was called the "Catskill" brick, made on the Hudson River, New York, and took about 44 per square yard as laid on a 6-in. concrete base. About 9 000 sq. yd. was laid at a cost of $2.67 per square yard.

While the bricks used were not of the hardest kind, no repairs were made until 1907, and from that time till the present various sums, amounting to $2 535.98, have been expended in repairs and renewals. The pavement is now practically worn out and

needs relaying. This would make, for the fourteen years of the pavement's life, an annual maintenance cost of $0.02 per square yard, which does not seem a bad showing for this street with its concentrated traffic.

Another street presenting conditions quite different from the last is Massachusetts Avenue from Harvard Bridge to Lafayette Square, one of the main thoroughfares from Boston to Cambridge. The roadway here is 60 ft. between curbs, and contains two street railway tracks and carries a large amount of traffic. The part from Harvard Bridge to the Boston & Albany Railroad crossing, containing about 9 000 sq. yd., was paved in 1901 with "Metropolitan" blocks, made at Canton, Ohio, on a 6-in. concrete base, taking about 42 per square yard. This part of the street contains a long curve and the street railway tracks, laid on a poor foundation of filling, soon showed great vibration and affected the brick paving near the track. This strip was repaired by the Boston Elevated Railway Company. Practically nothing has been expended on the paving for maintenance or repairs in the twelve years of its life, except as noted above. The pavement is now in poor condition in places and needs extensive repairs.

The other section of Massachusetts Avenue, between the Boston & Albany Railroad and Lafayette Square, was paved with the same kind of block in 1904. Nothing has been spent on this pavement for repairs during these nine years and it is now in excellent condition. The total area of this street is 18 145 sq. yd. and the average cost of the pavement was $2.75 per square yard. The street being wide and the excavation easy made the cost less than was found to be the case on narrow streets, as will be next referred to.

Another interesting condition exists on several very narrow streets, only 40 ft. wide, and having a single line of car track. In these cases the roadway is only 26.66 ft. between curbs, so that the traffic is greatly concentrated, almost into ruts. These streets — Pearl Street, Brookline Street, Putnam Avenue, etc. — were paved mostly with the Metropolitan block in 1901–2, 1904, and 1905.

The narrow roadway, with the presence of the car tracks, trees, etc., made the pavement cost a little over $3.00 per square yard. Nothing has been expended for maintenance, and these streets are now in good condition, where formerly it was impossible to maintain a macadam surface free from ruts and holes without constant reconstruction.

Up to 1910 only brick made principally from shale were used

in paving. In 1910 and 1911 a part of Putnam Avenue, a partly residence street 40 ft. wide, without car tracks, was paved with the "Mack" blocks, which are made largely from fire clay. The portion paved was about 2 700 ft. long and contained about 9 064 sq. yd. Parts of the street were high in grade and contained a large amount of hard macadam; this made the excavation cost very high. The net cost of the paving was $3.04 per square yard. While of course no conclusion can as yet be drawn as to the durability of the blocks, there can be no doubt that they make a very handsome and pleasing pavement, and seem admirably adapted to streets of this class carrying moderately heavy traffic. A marked decrease in the noise from traffic is noticed on this pavement.

There have also been used some bricks made at Johnsonburg, Pa., which have given very good service. The following is an approximate estimate in some detail of the average cost of brick paving in Cambridge under the present conditions using city day labor.

Paving bricks, 42 per square yard at $30 per M	$1.26
Excavation	0.35
Concrete base 5 in. thick, 1 : $2\frac{1}{2}$: 5	0.80
Sand cushion or bed in place	0.07
Filler, — cement grout and tar expansion joint	0.15
Labor, — paving and ramming	0.12
Miscellaneous expense, — superintendence, lighting, etc	0.25
Cost per square yard	$3.00

In localities where work is done by contract, or where labor conditions and freight charges for the bricks are more favorable than in Cambridge, undoubtedly a lower cost per square yard can be shown.

I should place the life of a brick pavement at from twelve to twenty years, depending on the character and amount of traffic and the quality of the bricks used.

The average yearly cost of a brick pavement for a term of years may be shown by a computation based upon the following assumptions, all construction work to be paid for by the issue of bonds.

Assumed life of brick pavement	13 years
Assumed life of concrete base	39 years
Assumed life of bonds	10 years, 3 issues
Assumed first cost of pavement	$3.00 per sq. yd.
Assumed cost of renewals	$2.10 per sq. yd.
Assumed cost of repairs	$0.02 per sq. yd. per year.

First bond issue interest, $3.00 x 4% x 10	$1.2000
First bond issue sinking fund, $3.00 x 0.08524 x 10	2.5572
Second bond issue interest (renewal), $2.10 x 4% x 10	0.8400
Second bond issue sinking fund, $2.10 x 0.08524 x 10	1.7900
Third bond issue interest, $2.10 x 4% x 10	0.8400
Third bond issue sinking fund, $2.10 x 0.08524 x 10	1.7900
Cost of repairs, 39 years at $0.02	0.7800
Total cost for 39 years	$9.7972
Cost per square yard per year	$0.251

It may be interesting to compare this yearly cost with the costs of other pavements based on appropriate assumptions:

Granite block pavement, annual cost 40-year period	$0.201
Wood block pavement, annual cost 40-year period	0.292
Bitulithic pavement, annual cost 40-year period	0.284
Tar macadam, annual cost 10-year period	0.296
Plain macadam, annual cost 10-year period	0.179

In comparing the above figures it should be remembered that these yearly costs can be realized only when the pavements are applied to traffic for which they are adapted. Thus if plain macadam was put on streets having heavy traffic for which only granite blocks are adapted, its yearly cost would then greatly exceed that of granite blocks.

All brick pavements should be laid on a firm, stable base. In most cases a cement concrete base from 4 to 6 in. thick, depending on traffic and soil conditions, will be found most satisfactory.

In Cambridge, in order to prevent the early breaking into a brick pavement for the purpose of relaying or repairing street conduits of any sort, the street to be paved is first examined to see that all public sewers and water pipes are in good condition, and are in no need of enlargement or repairs. All the public service corporations having locations in the street are then notified that no permits will be granted them for openings for laying conduits after the pavement is laid, for a specified time. And finally, every abutting owner is notified to have all repairs, alterations and additions contemplated in any service connection made before a specified date when the work will be begun.

Our experience in Cambridge would seem to warrant the following conclusions:

For streets carrying heavy freight and trucking, brick are not adapted. Nothing in my opinion is so well adapted for traffic of that grade as a good, well-cut, granite block pavement.

For streets having a fairly heavy mixed traffic, only the best, hard, evenly burned, shale brick should be used.

For streets carrying pleasure and light business traffic, the best grade fire clay brick may safely be used.

In selecting the best type of paving material for a given street, the concentration of travel is an important factor to be considered.

In selecting a paving material, it should be remembered that bricks are not subject to chemical deterioration or structural change, but they will be good until *actually worn out* in good, honest service.

Essential defects can readily be detected before laying by thorough inspection and tests. The scientific testing of bricks has now become so well standardized that fairly reliable and consistent results can be obtained from it, and should be employed in connection with the common " practical " tests by breaking or fracture, dipping in water for porosity and absorption, examination for laminations, texture " sulphur balls," etc.

In conclusion, I may say that the total mileage of brick pavement in Cambridge is now 3 890 miles, with an area of 83 415 sq. yd.

Mr. Charles F. Knowlton. — I did not expect to say anything to-night, but since Mr. French has made some reference to the work I have done, I suppose I might make a few remarks as to how the paving situation appears to me. In thirty years' time I have dealt with this question from all points of view, — as inspector, engineer, man in charge, city engineer and city official, — to determine the kind of paving; and finally as a contractor. Of all these different people I think the man who has to determine the kind of paving to use is the man who is up against it. He must realize his responsibility and select a pavement which is going to reflect credit upon himself; and it is a very difficult thing to select the right kind of paving to meet the conditions of traffic on the particular street on which you desire to put it.

There are all kinds of pavement, all kinds of streets and all kinds of traffic, and the city engineer who selects a pavement makes a careful study of all the conditions and selects a certain kind and plans it to be constructed. It is then practically out of his hands; another person constructs it. He cannot watch it every minute. There is an inspector perhaps over it who may be thoroughly honest, but inexperienced in that particular kind of work and unable to say whether the work is done very well or not.

Then perhaps it is put into the hands of a poor contractor. There are all kinds of contractors. The contractor might be an expert, experienced in his line and know the value of little details; and he will do a first-class job. He might, on the other hand, be a

contractor who has just started work and has had no experience. He would not realize, perhaps, that these little details make the difference between a good pavement and a poor one. Perhaps he has taken the job at a very low price and has got to make a profit somehow. I tell you that the success or failure of a pavement depends a good deal upon the way it is constructed, and I have realized it more and more since I became a contractor. When I was an inspector on this kind of work I had an idea that no contractor could bluff me or do any work that was not just right, but since I have become a contractor I can see many loopholes that an inspector never can see. So I say that the success of a pavement depends, in a large measure, upon the honesty of the man who constructs it. It does not turn out many times the way the engineer who selected it expects, and simply from the fact in many cases that it is not properly built. Now in relation to brick pavements, the success of a brick pavement to a large extent is in the grouting of the surface and the proper application of that grout. If the grout is strong, and is properly mixed and placed in the joints as it should be, and the sand not allowed to separate from the cement, that grout will hold the edges of the brick and they will wear a long time; but if this is not properly done, the bricks soon chip on the edges, and although the bricks do not wear out, still at the same time you are getting a rough and uneven pavement. Each brick wears a little turtle-backed, and in each joint a lot of mud collects in bad weather, and in the summer time there is a lot of dust. It is the same way with a grouted granite block pavement. The success of a brick or granite block pavement grouted with Portland cement largely depends on the way the grout is applied to the surface. Many of you have seen grout mixed and poured out of a box and the cement and water separate from the sand and flow to the sides, leaving sand only to fill the joints, and the pavement would never be a success and stand up under traffic. The grout must be strong, uniformly mixed and fill the joints to the full depth. In regard to the making of concrete bases, Mr. French referred to a compressed concrete base by the Hassam process. We believe that the strength of the concrete depends upon the amount of aggregate in it. You want just enough cement to hold that aggregate together; the same as a cabinet maker, when he glues pieces of wood together. If he gets his pieces of wood very close together and a very thin layer of glue between, it will stick much better than if there was a thick layer of glue between the two. The thinner you can get that layer of glue between the two pieces of wood, the better they

adhere. The theory is the same with concrete. You do not want any surplus. There is no strength in that surplus. Get enough in to hold the aggregate together. That is where we claim there is a great deal of strength in a compressed grouted pavement, because we get a large amount of aggregate and enough mortar to hold the stones together, — the stones themselves are rolled until they practically rest upon each other; in this way they will carry a very heavy traffic, much more than if resting on mortar alone.

In constructing a pavement on a concrete base the question of cost enters into the matter to a great extent, and the compressed grouted concrete is much lower in cost than any other. I believe that a concrete base should be put under every pavement that is laid, no matter whether it is brick, granite block, asphalt or bitulithic pavement. Any pavement to-day should be laid on a concrete base. Years ago they laid a 6-in. concrete base and put an 8-in. granite block on top of it. There was almost enough stability in the block to hold itself up without a concrete base. Then they laid a 2-in. asphalt pavement, and they put in a 6-in. concrete base just the same, without practically any strength in the asphalt itself, depending on the strength of the base. In the same manner they laid 4-in. brick with a 6-in. concrete base. The engineers began to think there was a waste of money laying granite block that way, spending so much for excavation for an 8-in. block on a 6-in. concrete base, and a change was made to a thinner base, and many cities now use a 4-in. base, which proves strong enough, especially if made under the Hassam process of compression by a steam roller. Then an agitation started for a shallow granite block, and the engineers in different parts of the country got together and adopted a standard block. There were some contractors who started out with a 4-in. block called the Hassam block, believing that if 4 in. of wood or brick would stand, then a 4-in. granite block ought to stand. As a compromise, however, the engineers adopted this standard block 5 in. deep. That has brought the cost down quite a little, especially where laid on a 4-in. compressed base. These small blocks are finely cut and laid with $\frac{1}{4}$- to $\frac{1}{2}$-in. joints and when filled with grout make a very smooth durable pavement.

For a grouted block pavement it has been found desirable to use a softer granite than if the joints were filled with sand or pitch. The soft granite does not wear to a glassy polish, but more like a grindstone, and always presenting a gritty surface does not prove slippery; also the granite and cement are of about

equal hardness and wear uniformly so that the pavement grows smoother instead of rougher under years of heavy traffic. Another paving which was used a number of years ago was the asphalt block pavement, as built out of Trinidad Lake asphalt and limestone compressed. That stood very well for awhile, but the limestone was of such a nature that it would not stand the traffic as well as had been expected, and it got a black eye for a while, but in the last few years asphalt blocks are made of Trinidad asphalt and trap rock, which is making an excellent pavement and can be laid as cheaply as a brick pavement, and is as attractive as sheet asphalt. This pavement is being laid to a great extent in Brooklyn, N. Y., at the present time. In fact, the factories which are making it are overrun with orders. That is a pavement I would like to see here in Boston and in some of these smaller cities around here. It is a notable fact that Boston is one of the last cities to adopt a new idea, in pavements especially. Wood block and brick and asphalt blocks were laid in the West and in the South before Boston took them up. The theory of bitulithic pavement is that it has no voids. The stones are so graded and brought together that the voids are reduced to a minimum and bitumen is put in to hold the stones together. The same theory applies to this asphalt block which I have spoken of, made out of trap rock and just enough bitumen added to cement the stone and fill the voids. The principle is the same as that on which the concrete pavements are made today. Concrete pavements have been introduced within a few years and are now used to a large extent throughout the country. One city after another has tried them. They have made mistakes and improved on them, so that to-day there is a lot of successful concrete pavement laid, through the West especially. A great many of the small cities are laying concrete pavements at a very small cost and getting a very durable pavement. The theory in these Hassam concrete pavements is, as I said, to compress the stone together and use just enough cement and mortar to hold them in place. Let the travel come upon the stone; and of course the harder the stone, the more durable the pavement. The objection to concrete pavements has been that they were slippery, noisy and more or less dusty. That has been obviated to-day by covering the concrete with a bituminous top. That makes a good pavement and wears similar to an asphalt surface.

In building their state highways, New York and Maine have adopted the concrete pavement with bituminous top, and they are laying miles and miles of it. They intend to make all their

state roads concrete roads with bituminous top. They have got to do it. With the introduction of the automobile and automobile trucks neither water-bound macadam nor bituminous macadam can stand up under the traffic. It is not the weight; it is not the downward pressure; but it is the shearing pressure or thrust, and no bituminous material alone can stand it. So they have got to have something which is firmer and which will not disintegrate, ravel or crawl. They are adopting, as I say, concrete pavements with bituminous top or bituminous pavements with concrete base, whichever way you put it. Vanderbilt has built over forty miles of that class of paving on his automobile race course. The way they decided to do this was, the engineer, who was formerly state engineer of New York state, had stretches laid five years ago of various forms of pavements, to see what effect the automobile traffic would have on them. He kept very close watch of these stretches of pavement, and the Hassam concrete pavement stood up under the automobile traffic better than any of the others. The bituminous top on this made a very pleasing pavement, although the bituminous top does not last very long. The durability of this top surface lies entirely in the character of the bitumen. As Mr. Sullivan said, for forty years they have been experimenting on asphalt and they have not got it down fine yet. For forty years they have been getting tar from gas houses, and building streets, sidewalks, etc.; and nobody to-day can tell you what kind of a mixture to make for any sidewalk or street. You have got to depend on the old Tad who has mixed tar year after year, and who can tell by the looks of it when it is dipped up whether it is right or wrong. He can tell by putting a piece in his mouth and chewing it. All your tests and examinations will tell you nothing, and you cannot be sure about its durablity. It will go to pieces in one street and stand up well in another. One tank of tar will wear well and another tank will not. It is difficult to tell from any chemical analysis where the difference lies. You ask the old Tad who mixes for tar street crossings, etc., how much pitch he has to put into every barrel of tar to bring it to the right strength to hold the stone together and have the proper ductility, and he will tell you that he has no definite amount. He will take a barrel of tar, empty it into the kettle and heat it, and when it is up to the right temperature, having heated the pitch in another kettle, he will pour some pitch in and try it, then perhaps put in some more and try it. I have heard them say that they put in anywhere from two dippers to eighteen dippers of pitch in a kettle of tar in order to

get it right and satisfactory for street work. That is just the way tar works. That is why I say you must not depend upon bituminous mixtures as being always durable. You may hit it right and you may not.

Speaking of concrete bases 4 in. thick, there is a point which I think engineers ought to consider in justice to the cities. Of course they want to save all they can. Some streets will stand on that base and other streets will need a greater thickness. I remember in Duluth a paving with the old round cedar blocks. There was a water trench through the main street and they were to put this paving on top of that, and the engineers thought it would settle, so they laid a concrete base 8 in. deep over the entire surface of the street. It only needed 8 in. over that trench and possibly a foot or two outside of it to bridge it, but 8 in. was placed all over the street. That was a waste of money, to waste 4 in. of concrete on 80 per cent. of the surface, where it was not needed, just for the sake of making, say, 20 per cent. of it perfectly safe. I think engineers, by making a study of such situations, could save a lot of money and reduce the cost of pavements.

I just want to say one word for the contractor on the question of bidding. I want to bring this thought to the attention of the engineers representing municipalities. Is it the best policy in awarding contracts to let them to the lowest bidder in all cases? In lots of cities one is obliged to let the job to the lowest bidder to cover the by-laws, but do they get the results they should get? If they wanted to buy a suit of clothes they would not buy the cheapest in the market. If they wanted to buy building material they would not stick for the cheapest. They would go to the people who have a reputation for right dealing and for selling good materials and they would pay a good price and be satisfied that they had received something in return, but when it comes to letting out public work they advertise for bids and everybody comes in and bids. The man who has made a life study of this particular kind of work, who has been brought up in the community and always lived there with his family, has to bid against the man who has just come to town with his carpet-bag, and the man with the carpet-bag usually is the lowest bidder and gets the job. He will do everything he can to make something out of it, even if he has to jump out of town without paying his honest bills and leave the local merchants in the lurch. That happens right along in nearly every community with which I have been connected in any way. I know of one city which was organized under a new charter. The new commissioners passed a vote

that they would advertise for bids on everything and would let jobs to the lowest bidders. They established that rule. The first thing they advertised for was a pair of horses. They got all kinds of bids, from $100 to $800 a pair; but they were going to let the job to the lowest bidder. The next thing they advertised for was hay, and they got prices from $12 a ton up to $28 a ton. They let the lowest bidder furnish the hay. What was the result? They had to throw the hay in the manure heap. The horses went to the soap man. After that they decided that they would use a little judgment and award their contracts to the people whom they thought would furnish the proper kind of material and give them what they had advertised for. So I believe that it is cheaper in the end, and better work would be done, by letting a contract for the best interest of the city, using some judgment in the matter rather than taking the lowest bidder in every case. Look up the contractor, find out his reputation, his financial standing, his character, and then let the contract accordingly to the man who will do the best work for the money; and I believe the taxpayers would be satisfied that the city officials were honest enough to award these contracts properly. I think the idea of awarding a contract to the lowest bidder ought to be stopped, in order to get honest work done.

[NOTE. — Further discussion of this paper is invited, to be received by Joseph W. Peters, Secretary, 3817 Olive Street, St. Louis, Mo., by January 15, 1914, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

George Alfred Nelson.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

GEORGE ALFRED NELSON was born at the Nelson homestead in Lincoln, September 20, 1852. He was the son of George Nelson and Abigail Marion Bigelow Nelson, who lived in the old homestead. This had a special interest on account of the Revolutionary events centering about the midnight ride of Paul Revere, who was captured by a British patrol on the Nelson farm early in the morning before the battle of Lexington.

Mr. Nelson received his earlier education in the Lexington district schools and the Lincoln High School. He spent a year at home after graduating from the High School and entered the Massachusetts Institute of Technology in 1873, completing his four years' course in civil engineering in 1877. He was connected with the survey and construction of the railroad up Mount Washington, during his summer vacation, being an assistant to Mr. Chas. Lund, C.E., of Concord, N. H. During his course at the Institute he was painstaking and thorough in his studies and won the respect of the professors and his classmates with his conscientious work and genial manner. He was very skillful with pencil and crayon, and frequently his problems at the blackboard were illustrated in a very ingenious manner, and during the political campaign his cartoons were worthy of a Thomas Nast.

After completing his course at the Institute he spent two years at his home engaged in surveying and engineering work in the vicinity. He then came to Lawrence as sketch maker in the designing department in the Pacific Mills, where he remained four years. In 1883 he resigned and accepted a position as assistant engineer in the city engineer's office in Lowell, Mass., a position which he held at the time of his death. He had charge of bridge construction, water-works improvements, extensions in sewer department and city surveys for assessors' maps. The city surveys involved an extensive system of triangulation and accurate location of all lots and street lines, and the work was carried out with precise methods. He designed and supervised the construction of the Taylor stone arch bridge across the Concord River. The location of the bridge involved difficult foundations, and the successful completion of the structure showed the thought and skillful design that were

devoted to the work. The wooden block pavement on the Centralville bridge across the Merrimac River is an example of thorough work under his careful planning and supervision and has stood the test of many years.

He had a fine, strong character, which impressed all with whom he came in contact, and his constant attention to details affected his health so that he was forced to seek rest at intervals. He found recreation in the snowshoe trips of the Appalachian Mountain Club, and also an occasional summer outing. He was an expert photographer and his artistic ideas regarding the composition of a subject and his technical skill in the use of the lens made him most successful in this department. He received many medals for his pictures in various exhibitions in the United States, and his work was selected with a few others to represent the United States in an international exhibit at Berlin, Germany. At this exhibition he received a silver medal for his work.

He was a member of the Eliot Congregational Church Society and took a keen interest in its work. He was for many years the president of the John Eliot Literary Society and through his active energy and personality the work of the society was most successful. He contributed papers on the subject of art and composition which showed the feelings of a true artist. He was a member of both the American Society of Civil Engineers and the Boston Society of Civil Engineers; and designed the society pin which was adopted by the Boston Society. He was also a member of the Appalachian Mountain Club; the Alumni Association of the Massachusetts Institute of Technology; the Technology Club of the Merrimac Valley, of which he was an active president for several years; and the Association of the Class of 1877 of the Massachusetts Institute of Technology. He was a member of the Vesper Country Club at Lowell and was an expert golfer, working out various details on a scientific basis.

His personality and keen mind impressed all with whom he came in contact, and the world is much better for the work which he has accomplished and the influence left in the memories of all who knew him. His constitution was not very rugged and he developed a kidney trouble, resulting in his death on June 3, 1913, after a few months' illness.

He was never married. He leaves a married sister living at Lincoln, and two brothers who reside in the Nelson homestead.

RICHARD A. HALE,
GEORGE BOWERS,
Committee.

Edward A. Haskell.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

EDWARD A. HASKELL, a member of this Society, died at his home in Newtonville, August 24, 1913, of an illness of nearly two years' duration.

He was born at Deer Isle, Me., August 10, 1864, and came to Boston at the age of ten years. He was educated at the East Boston public schools, Chauncy Hall, and Massachusetts Institute of Technology, Class of 1887, where he took the course in civil engineering.

He was first employed by Mr. Alexis H. French, of Brookline. In 1887 he entered the service of the Boston & Albany Railroad as surveyor on Division 1, and continued in the service of that road up to the time of his death. In 1894 he was appointed roadmaster of the Second Division, with headquarters at Springfield. In 1903 he was transferred to Pittsfield, where he had charge of the Third Division. In 1907 he was appointed division engineer with headquarters at Boston. The completion of the four tracks to South Framingham was done at this time under his supervision, and also the large freight yard at Beacon Park was built.

He became a member of this Society February 17, 1909. He was also a member of the Springfield Lodge of Masons and a member of the New England Railroad Club. At one time he was president of the New England Roadmasters Association, and was always active at the Association's annual conventions.

Mr. Haskell leaves an enviable record among the officers and men of the Boston & Albany Railroad for exceptional ability and integrity. His ideals were high and he was successful in attaining them. He was beloved and respected by all who knew him as a man of the highest type of refinement and character.

Besides his widow, who was Miss Linda M. Graves, he leaves two sons, Paul C., of New York, and Allan G., of Boston.

LUIS G. MORPHY,
JOHN B. RUSSELL,
Committee.

ASSOCIATION
OF
ENGINEERING SOCIETIES

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PROCEEDINGS.

Boston Society of Civil Engineers.

BOSTON, MASS., FEBRUARY 19, 1913. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order at eight o'clock by its President, James W. Rollins; 112 members and visitors were present.

The reading of the record of the last meeting was dispensed with, and the record was approved as printed in the February *Bulletin.*

The Secretary reported for the Board of Government that the following candidates had been elected to membership in the grades named:

Members — Messrs. Thomas Abbott Baldwin, Arthur Rosengarten Nagle, John Theodore Tobin and Clifford L. Wade; and as Juniors — Edwin Andrew Desmond and Charles Kirk McFarlin.

The Secretary proposed for the Board of Government the following amendment to the By-Laws which had been printed in the notice of the meeting:

Amend By-Law 7 by adding at the end of the second paragraph the following words: "Applicants who may be so situated as not to be personally known to four members may be recommended by three members of the Board of Government." On motion of Mr. Fay, the amendment was adopted by a unanimous vote.

The President announced the death of Albert S. Cheever, a member of the Society, which occurred on February 17, 1913, and in accordance with the usual custom a committee was appointed to prepare a memoir; it consists of Messrs. Henry W. Hayes and J. Parker Snow.

On motion of Mr. Gow, the thanks of the Society were voted to those who had extended courtesies to its members on the occasion of the excursion this afternoon to the Commonwealth Pier and the New Fish Pier at South Boston: Gen. Hugh Bancroft, Chairman of the Directors of the Port of Boston, Messrs. Monk & Johnson, the H. P. Converse Company, and Tyson, Weare & Marshall.

The following papers were then presented and read:

"A Small Bascule Highway Drawn Span," by Prof. Lewis E. Moore. "An Account of Some Early Experiments upon Reinforced Concrete," by Prof. Charles M. Spofford. "Some Notes on Highway Bridge Floors," by Frederic H. Fay.

The lantern was freely used in illustrating these papers.

Mr. Joseph R. Worcester presented a paper entitled, "Initial Stresses in Steel Sections," and on his suggestion the paper was read by title only. It will be printed in an early number of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., APRIL 16, 1913. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, at 7.50 o'clock, President Frederic H. Fay in the chair, 75 members and visitors present.

The reading of the record of the annual meeting of March 19, 1913, was by vote dispensed with and approved as printed in the April *Bulletin* with the addition of the full report of the tellers of election.

The President reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Messrs. Randolph Bainbridge, Frederic Bonnet, Jr., Clarence Elmore Carter, Frederick M. Gibson, Lorenzo Gordon Moulton, Frank Cummings Shepherd, George M. Stevens and George Frederick Temple.

Junior — Mr. Charles Vaughn Reynolds.

He also reported that the Board had elected the Secretary to serve as Librarian over the ensuing year and had appointed, under authority of a vote of the Society passed at the annual meeting, the following committees:

On Excursions — Charles R. Gow, Edmund M. Blake and James B. Flaws.

Library Committee — S. Everett Tinkham, Frederic I. Winslow and Charles M. Spofford.

On Publications and to represent the Society on the Board of Managers, Association of Engineering Societies — S. E. Tinkham, Dexter Brackett, C. W. Sherman, H. P. Eddy, A. T. Safford, J. R. Worcester, H. F. Bryant and E. R. Olin.

The committee, Messrs. J. P. Snow and H. W. Hayes, appointed to prepare a memoir of our late associate, Albert S. Cheever, submitted its report, which was read by the Secretary. He also read the report of the committee, Messrs. J. R. Worcester, J. W. Rollins and C. T. Fernald, appointed to prepare a memoir of Past President George A. Kimball. Both memoirs were received and ordered printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The President called attention to the proposed joint dinner of the engineers of Boston which will be held at the Boston City Club on April 29, 1913, and stated notices would be sent out in a few days giving full information.

On motion of Mr. Sherman, it was voted that the regular June meeting of the Society be held on such a date as the Board of Government may select.

S. E. TINKHAM, *Secretary.*

ANNUAL MEETING OF THE SANITARY SECTION.

BOSTON, MASS., MARCH 5, 1913. — The annual meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening at the Engineers Club, corner of Commonwealth Avenue and Arlington Street.

Dinner was served to 48 members and guests shortly after six o'clock in

the main dining room of the Club. The chef and his assistants established a reputation for themselves, both as to quality of food and service, which, together with the courteous attention rendered by the other employees, made a most favorable impression.

At the close of the dinner, the members adjourned to the Assembly Hall on the ground floor, where the business meeting was called to order at 7.30 o'clock by Chairman George C. Whipple.

The chair announced that unless there were objections, the reading of the minutes of previous meetings would be omitted and the minutes approved as printed in the *Bulletins* of the Society. No objections were raised and accordingly the minutes were declared approved as printed.

The Committee on Rainfall and Run-off, Mr. George A. Carpenter chairman, submitted a brief progress report. A motion was made, seconded and carried that the report be accepted and placed on file.

The report of the Executive Committee of the Section was read by the Clerk. Upon motion made and seconded, it was voted to accept the report and to place it on file.

Mr. Edward Wright, Jr., reported for the Nominating Committee the following nominations for officers to serve for the ensuing year:

Chairman — Edmund M. Blake.

Vice-Chairman — Hector J. Hughes.

Clerk — Frank A. Marston.

Members of Executive Committee — George C. Whipple, George A. Sampson, Ezekiel C. Sargent.

On motion of E. P. Adams, duly seconded, it was voted to accept the report, and to instruct the Clerk to cast one ballot for the officers as nominated.

The Clerk cast a ballot as instructed, and the officers were declared elected to serve for the year ending March, 1914.

Under the item for new business, Mr. George A. Carpenter requested the privilege of recalling to the minds of the members the fact that during the past year the Chairman of the Section had always been ready to do his duty, no matter in what direction that might lead, and that as a proof of this fact he desired to submit a few lantern slides made from photographs taken on the June excursion in Worcester. These photographs showed the sludge from the experimental Imhoff tank in various stages of drying. The last of the series caused considerable amusement as it showed "The Chairman Attending to His Official Duties" even to the point of holding sludge within two inches of his nose to prove that the nauseating odor had entirely disappeared.

As there was no further business to be acted upon, the Chairman introduced, as the speaker of the evening, Shaoching H. Chuan, M.D., of Pekin, China, who gave a most interesting and unique talk upon "A Glimpse of Tibet." Dr. Chuan showed that during his year's stay on "The Roof of the World" he had been a careful student of the country and customs, and that by the unusual collection of lantern slides, numbering more than one hundred, he had used his camera to good advantage. As medical officer of the Chinese Mission to Tibet, Dr. Chuan was privileged to photograph many objects that would be forbidden to the usual tourist. His descriptions, although brief, were to the point, and when enlivened by a keen sense of humor, they made the talk one to be remembered. It was clearly brought out that although Tibet is an enormously rich country for its size, the people as a majority live in primitive life amidst the worst forms of religious superstition and degradation.

A considerable portion of Dr. Chuan's talk, together with sixty illustrations, will be founded in the *National Geographic Magazine*, Vol. 23, No. 10, October, 1912, p. 959.

A vote of thanks was extended the speaker for his courtesy in giving such an instructive and interesting talk.

Chairman George C. Whipple then introduced Mr. Edmund M. Blake, who spoke briefly in appreciation of the honor conferred upon him, and of his purpose to do all in his power to make the ensuing year one of continued activity in the Sanitary Section.

There were 68 present at the meeting. Adjourned at 9.30 o'clock.

FRANK A. MARSTON, *Clerk*.

Technical Society of the Pacific Coast.

REGULAR MEETING held on May 16, in the auditorium of the Young Men's Christian Association, 220 Golden Gate Avenue, San Francisco.

The meeting was called to order at 8.30 o'clock P.M. by President G. Alexander Wright.

The reading of the minutes of previous meetings was dispensed with.

Mr. Wright, before introducing the speaker, referred to the work of the Technical Society and of the plans that had been made for its future activity, and of the papers and subjects that are to be presented for reading and discussion.

After a short address of this character he introduced Mr. Hermann Schussler, the consulting engineer for the Spring Valley Water Company, who delivered an elaborate address, of a technical character, on the subject of "Water Supply of Modern San Francisco and Ancient Rome."

This lecture proved to be of great interest to a highly appreciative audience whom the members of the Society had invited to attend, the meeting having been made open to the public.

After Mr. Schussler's address the meeting adjourned.

OTTO VON GELDERN, *Secretary*.

Louisiana Engineering Society.

NEW ORLEANS, MAY 13, 1913. — The regular meeting of the Society was called to order with President Shaw in the chair and 42 members and guests present.

The minutes of April 14 were read and approved.

The technical exercises of the evening were then proceeded with. Dr. J. F. Oechsner read an excellent and very interesting paper on "The Sanitation of Construction Camps and First Aid to the Injured."

A communication was read concerning a call for a mass meeting about floods.

Mr. J. F. Coleman said a few words informally on the coming visit of the American Society of Civil Engineers to this city.

There being no further business, the meeting adjourned to the usual collation.

JAMES M. ROBERT, *Secretary*.

Utah Society of Engineers.

Salt Lake City, Utah. — The regular meeting of the Utah Society of Engineers was held at the headquarters in the Mining Exchange Building on Friday evening, May 16, 1913.

Meeting called to order by President Peters at 8 P.M.; about 65 members and friends present.

The minutes of the previous regular meeting were read and approved. Report of various actions taken by the Executive Committee was made, and the selection of the chairman and members of the following committees was announced, viz.:

Program Committee — Chairman, Leonard Wilson; H. J. Harris and W. A. Wilson.

Entertainment Committee — Chairman, Murray Sullivan; Markham Cheever, J. H. Tempest, Julian Bamberger and H. D. Randall.

Membership Committee — Chairman, H. W. Sheley; A. B. Villadsen, H. H. Dalton, S. S. Arentz and R. K. Brown.

Representative to Association Board of Managers — R. K. Brown.

The application of Burton Fremont Dinsmore, of Ogden, Utah, as Associate Member was balloted on and unanimously accepted.

Following the business meeting, Mr. L. M. Bailey, general manager of the Portland Cement Company of Utah, read an interesting paper on the manufacture and uses of Portland cement, giving an account of the early and present day development of the Portland cement industry in Utah. After the reading of the paper, various points were discussed as follows:

Designs of Structures, by Mr. Bacon.

Retrogression in Tensile Strength as Developed by Neat Tests. This subject was discussed at length by Messrs. Ronk, Pierce, Sullivan, Davis, Brown and others.

Failures in Concrete Due to Materials, by Messrs. Villadsen, Goodrich, Brown, Sheley, Randall and others.

Various Aggregates Available at Salt Lake, by Messrs. Goodrich, Randall and others.

Tests of Cement Mixed with Water from the Great Salt Lake, by Mr. D. J. Davis.

"The effect of freezing," "The personal equation of the person making the test," and many other features were brought out in the general discussion.

On invitation of Mr. L. M. Bailey, the Society decided to visit on Saturday afternoon, May 17, the plant of the Portland Cement Company of Utah, situated at Salt Lake.

After a vote of thanks to Mr. Bailey for his paper, the Society adjourned.

Fred D. Ulmer, *Secretary.*

Association of Engineering Societies

Vol. LI. AUGUST, 1913. No. 2.

PROCEEDINGS.

Invitation to International Engineering Congress in 1915.

A cordial invitation has been extended to the members of the societies constituting the Association of Engineering Societies to attend and participate in the proceedings of the International Engineering Congress to be held in connection with the Panama-Pacific International Exposition at San Francisco, Cal., September 20–25, 1915, under the auspices of five national societies, viz.: The American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the Society of Naval Architects and Marine Engineers.

Engineers throughout the world will be invited to participate. The honorary officers of the Congress will consist of a president and a number of vice-presidents selected from among the most distinguished engineers of this and foreign countries.

The papers presented at the Congress will naturally be divided into groups or sections. During the Congress each section will hold independent sessions, which will be presided over by a chairman eminent in the branches of engineering covered by his section.

The scope of the Congress has not as yet been definitely determined, but it is hoped to make it widely representative of the best engineering practice throughout the world, and it is intended that the papers, discussions and proceedings shall constitute an adequate review of the progress made during the past decade and an authoritative presentation of the latest developments and most approved practice in the various branches of engineering work.

The papers, which will be collected and published by the Congress, should form an invaluable engineering library, and it is intended that this publication shall be in such form and at such cost as to become available to the greatest possible number.

The various committees are now actively at work and it is hoped that further and more definite announcements as to the membership fees, schedules of papers, etc., can be made in the very near future. The permanent Com-

mittee of Management consists of the presidents and secretaries of the five societies above named and eighteen members resident in San Francisco. Of that committee the chairman is Prof. Wm. F. Durand and the secretary-treasurer is W. A. Cattell. Address: Foxcroft Building, 68 Post St., San Francisco, Cal.

Engineers' Club of St. Louis.

THE 740th meeting of the Engineers' Club was held at the Club rooms at 3817 Olive Street, on Wednesday evening, May 7, as a joint meeting with the St. Louis Branch of the American Society of Engineering Contractors. The total attendance was 85.

President Hunter called the meeting to order and introduced Mr. Knight, of the American Society of Engineering Contractors, who presided.

Mr. C. E. Smith, bridge engineer of the Missouri Pacific Railway, presented an illustrated paper on "Moving the Kaw River Bridge." The paper described the raising of the three 180-ft. spans, moving them both laterally and longitudinally, and the construction of an additional span while under traffic.

Adjourned.

W. W. HORNER, *Secretary.*

The 741st meeting of the Engineers' Club was held at the Club rooms at 3817 Olive Street, on Wednesday, May 21, at 8.30 P.M., with a total attendance of 40. President Hunter called the meeting to order and requested Mr. M. L. Holman to take the chair. The minutes of the 739th and the 740th meetings were approved and report of the 531st meeting of the Executive Committee was received.

A letter fron the Paint, Oil and Drug Club was ordered filed.

Mr. W. E. Bryan, as secretary of the St. Louis members of the Board of Managers, made a statement in regard to the suggested withdrawal of the Club from the Association of Engineering Societies.

He stated that members of the Board and a majority of the Executive Committee favored withdrawal on the ground that the cost of the JOURNAL was out of proportion to its value to the Club. In a discussion of the subject by Messrs. Greensfelder, Schuyler, Woermann, Toensfeldt, Hunter, Wheeler, Holman and Bryan, it was brought out that the effect of our withdrawal on the publication of our papers, on our non-resident membership, our relation to the Boston Society of Civil Engineers and in the Association as a whole, must be carefully considered.

On motion of Mr. Greensfelder and seconded by Mr. Toensfeldt, the question of withdrawal was made a special order of business for the meeting of June 4, after which it should be submitted to letter ballot. The members of the Board of Managers were instructed to gather all data on the subject and to make a report on all points raised.

Mr. Holman, as chairman of the Committee on the Joint Charter Conference, reported that the work of the Charter Conference was completed and that one member of this committee, Mr. Flad, was now a member of the Board of Freeholders.

Mr. Spoehrer announced that a trolley ride, smoker and a play would be given by the Club on June 14.

Mr. Humphrey called the attention of the meeting to the death of Mr. Geo. D. Rosenthal. Messrs. Humphrey, Spoehrer and Langsdorf were appointed a committee to draft resolutions of respect and to prepare an obituary for publication in the JOURNAL.

Mr. W. O. Pennell, equipment and building engineer for the Southwestern Telephone and Telegraph Company, in an illustrated paper described how the design of a telephone plant is affected by experience with fires, storms and disturbances.

Adjourned 10.40 P.M.

W. W. HORNER, *Secretary.*

THE 742d meeting of the Engineers' Club was held at the City Club, on Wednesday, May 28, 1913. This was a special meeting to which the ladies were invited. The total attendance was 149.

Mr. V. A. Fynn gave an illustrated talk entitled, "Above the Snow Line." He decribed mountaineering in the Alps and showed views of many of the famous peaks and details of the ascents.

After the lecture, a buffet supper was served, and the Union Electric Orchestra gave a concert.

Adjourned 11.00 P.M.

W. W. HORNER, *Secretary.*

THE 743d meeting of the Engineers' Club was held at the Club rooms at 3817 Olive Street, on Wednesday, June 4, at 8.30 P.M., Vice-President Greensfelder presiding. There were 28 members and 2 visitors present.

The minutes of the 741st and the 742d meetings were approved.

The Chairman called for a report, by the members of the Board of Managers, on the advisibility of the Club withdrawing from the Association of Engineering Societies. Mr. Bryan read the report hereto attached, in which it was recommended that the Club withdraw.

Mr. Schuyler moved that the Secretary be instructed to take a letter ballot on the following:

"*Resolved*, that the Engineers' Club withdraw from the Association of Engineering Societies at the end of the fiscal year."

As an amendment, Colonel Ockerson moved that the arguments for and against withdrawal be printed and mailed to the membership with the ballot. Mr. Schuyler accepted the amendment.

After a protracted discussion of the subject, a complete stenographic report of which is hereto attached, the motion was adopted.

Mr. A. S. Langsdorf, as committee chairman, presented a draft of a new constitution, which he read. Several members objected to the draft of Article I, and suggested a revised form for this article. Mr. Pfeifer moved that the committee revise Article I in accordance with the suggestions offered, and that it then be submitted to letter ballot.

This was amended so that both the committee's draft and the revised draft be printed on the ballot and a vote taken on each. The motion as amended was carried.

Adjourned 10.20 P.M.

W. W. HORNER, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR meeting held in the Board Room of the Mechanics Institute on Friday evening, June 20, 1913.

The meeting was called to order at 8.30 o'clock by President G. Alexander Wright. The minutes of the last regular meeting were read and approved.

Mr. Marsden Manson came to the meeting prepared to address the members on the subject of the flood control of the Sacramento Valley, but it so happened that the members of the local association of the American Society of Civil Engineers held their meeting on the same evening, and coincidentally the subject to be discussed by them at this meeting was the same as that prepared for the Technical Society by Mr. Manson, Mr. F. H. Tibbetts having submitted a paper for discussion on flood control projects for the Sacramento Valley.

In view of this condition, it was moved that the Technical Society adjourn its meeting, and that the members present go in a body to the Palace Hotel, to attend the meeting of the local members of the American Society of Civil Engineers and that they there participate in the discussion of the paper to be read by Mr. Tibbetts.

This was done, and Mr. Marsden Manson spoke on the subject after Mr. Tibbetts had closed his address, and after Mr. C. E. Grunsky had discussed the great problem of river control in a general way.

The paper prepared by Mr. Marsden Manson will be submitted for publication in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

OTTO VON GELDERN, *Secretary.*

Association of Engineering Societies

Vol. LI. SEPTEMBER, 1913. No. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, May 21, 1913. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, at 8.15 o'clock, President Frederick H. Fay in the chair; 75 members and visitors present, including ladies.

The reading of the record of the regular meeting in April was dispensed with and it was approved as printed in the May *Bulletin*.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Messrs. Lawrence H. Allen (transferred from Junior), Frank Adams Baker, Thomas Francis Dorsey and John P. Wentworth (transferred from Junior).

Juniors — Messrs. Edward Porter Alexander, Pablo Beola and Frank Jay Jerome.

The Secretary also reported for the Board that it had received a report from a committee appointed to consider the feasibility of the Society publishing its own transactions and that by a unanimous vote had accepted the report and adopted the recommendation therein made. The Board also voted to submit the report to the Society at this meeting with the suggestion that the recommendation be submitted to letter ballot, to be canvassed at the June meeting. The Secretary then read the following report:

Boston, May 17, 1913.

To the Board of Government of the Boston Society of Civil Engineers:

Your Committee appointed to consider the desirability of withdrawing from the Association of Engineering Societies and the probable cost of publishing an independent journal has carefully considered the matter and reports as follows:

The Association of Engineering Societies was formed in 1881 with four societies as members: The Boston Society of Civil Engineers, the Engineers' Club of St. Louis, the Civil Engineers' Club of Cleveland and the Western Society of Engineers.

The objects of the association are outlined in the preamble to the articles of Association as follows: "For the purpose of securing the benefits of closer union and the advancement of mutual interests, the engineering societies and clubs hereunto subscribing have agreed to the following Articles of Association."

Article I is as follows: "The name of the association shall be 'The Association of Engineering Societies.' Its primary object shall be to secure a joint publication of the papers and transactions of the participating societies."

In the first issue of the JOURNAL the Board of Managers make the following statement showing the ambition of the promoters of the association and of those responsible for its management during the first year of its existence:

"The association has been called into being by no narrow spirit. Many of its promoters believe that local engineering societies should be established and fostered in every center of population where the engineering profession is sufficiently strong to support one; thus bringing each member within the easiest possible reach of his society. They also believe that these local societies should be brought into affiliation by some association with a wider sphere of action, by means of which common purposes may be executed, and through which their energies may be stimulated to high professional aims.

"While many have been actuated by this broad spirit, the coöperation of these widely separated societies has been, perhaps, mainly secured through a desire to effect an interchange of professional papers. . . .

"May we not hope that this act of coöperation is merely the initial stage in the development of an organization from which more than the interchange of papers will be realized and for which we may reasonably predict a great future? We surely indulge the belief that the articles of association were not only begotten in a generous spirit and are not only founded upon correct principles, but that they possess sufficient vitality and adaptability to permit growth in any direction which experience may indicate as desirable; that by wise counsel and the cultivation of a professional *esprit de corps*, an organization will ultimately be evolved from this beginning which will perform a work not now being done by any association in the land; a work beneficial to the participating societies as societies and to every engineer who desires a better tone and higher standing for the engineering profession."

In the thirty-three years of the existence of the association the hopes of the promoters have not been realized, and the objects for which it was founded, other than the interchange of papers, have been lost sight of. The association now simply exists for the publication of such papers as the different societies may wish to have published and may send to the secretary for that purpose. The desirability of remaining in the association depends, therefore, entirely upon the relative advantages of the joint publication and of the independent journal.

It is interesting to note that of the four societies which founded the association, only one besides the Boston Society of Civil Engineers remains in the association, the others having withdrawn, and they are now publishing their own journals, while the remaining society, the Engineers' Club of St. Louis, is contemplating similar actions. Twenty different societies have joined the association at different times and eleven of them have withdrawn for various reasons. The association now numbers nine societies, and the number of JOURNALS sent to each society, which represents approximately the membership of the society, is as follows:

Boston Society of Civil Engineers,	874
Engineers' Club of St. Louis,	363
Civil Engineers' Society of St. Paul,	62
Montana Society of Engineers,	122
Technical Society of the Pacific Coast,	91
Detroit Engineering Society,	307
Utah Society of Engineers,	112
Oregon Society of Engineers,	193
Louisiana Society of Engineers,	190
	2 314

The number of papers which have been published in the JOURNAL, with the total number of pages contributed by each society, during the ten years 1903 to 1912 inclusive, is shown in the following table:

	Papers.	Pages.
Boston Society of Civil Engineers,	119	2 728
Montana Society of Engineers,	28	291
Civil Engineers' Club of Cleveland,	16	222
Engineers' Club of St. Louis,	50	784
Louisiana Engineering Society,	24	440
Engineers' Society of Western New York,	6	94
Technical Society of the Pacific Coast,	48	685
Detroit Engineering Society,	20	256
Toledo Society of Engineers,	4	52
Engineers' Club of Minnesota,	6	52
Civil Engineers' Society of St. Paul,	11	117
Utah Society of Engineers,	8	124
Engineers' Society of Milwaukee,	3	38
Oregon Society of Engineers,	8	86
	351	5 969

From the above it will be seen that the Boston Society has furnished an average of about 12 papers per year to the JOURNAL, containing about 273 pages of text, or nearly one half of the total.

We believe the desirability of the society having its own journal, provided the expenses will not be materially increased thereby, will be conceded by every one. The only possible advantage of the joint publication, other than saving in expense, is in receiving the published papers of the other societies, but most of the members, we believe, would prefer to have the smaller journal without the papers contributed by the other societies, and have the papers which are presented to our own society printed promptly with written discussions, than to have the present bulky volume containing many papers of little interest to engineers in this section of the country.

The publication of an attractive journal under the name of the Boston Society of Civil Engineers will give the society a much better standing. There is very little now by which the public can learn that there is a Boston society of civil engineers. It has one publication in which none but members of the society are interested. The papers are published in a journal in which the name of the society appears with many other names in an inconspicuous place. The society gets no advantage from exchanges, as it has nothing to exchange.

We believe that the advantages to the society of having its own journal far outweigh the disadvantage of losing the papers presented by other societies, and that the only consideration which should keep us from taking such steps as would lead to an independent publication is that of expense.

If the society should publish its own papers, we believe that the best method of doing so would be to incorporate them in the *Monthly Bulletin*, which is now issued ten times a year, printing them in advance if possible, otherwise immediately after their presentation, inviting written discussion by the members. The most important discussions should also be printed promptly in the *Bulletin*.

At the end of the year, or oftener if the number of papers warrants it, all of the papers and discussions should be printed in one volume which can be sent to the members, bound, if they so desire. In this way the papers would reach the members promptly, and the written discussions could be placed with the papers, when they are finally printed, instead of in some subsequent volume as at present. This would involve printing the papers twice, but the extra expense of this would not be large, as the pages could be electrotyped at small cost.

We find the present cost to the society of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES is about $2 000 per year. The cost of the *Bulletin*, not including postage, is between $650 and $700 per year. It is therefore fair to assume that, if the present arrangement is continued, the cost to the society of its publications will be about $2 700 per year.

The best evidence as to the probable cost of an independent publication is that furnished by the *Journal of the New England Water Works Association* which is issued quarterly. The total number of pages in this journal in 1911, which was apparently a typical year, was 654, and the edition was 1 000. Our

edition would be substantially the same, and the total number of pages under present conditions, not including the reprinted papers which would be sent to the members in one volume at the end of the year, would not be far different. The Water Works Journal is published quarterly, while ours would be issued in ten numbers, increasing the expense to our society very slightly.

The gross cost of the Water Works Journal for 1911 was $2 626, but from that, in order to compare it with the cost of our JOURNAL, must be taken the advertising agent's commission, the cost of reporting meetings and the amounts received for reprints, which leave $2 170. This includes $300 paid to the editor, a part of which, with our organization, would undoubtedly be saved.

It is safe to assume that, exclusive of the volume of reprinted papers, the cost to the society would not be in excess of $2 200 a year. The getting together of the papers in one volume would consist simply in assembling and printing. The expense of this would not be more than $300, making the total cost of the publications of the society $2 500 per year, or $200 less than the amount now paid for this purpose.

The advertising space in the new bulletin should be of more value than at present, and the income from this source might reasonably be expected to materially increase. The exchanges which we would receive would save a considerable sum which is now expended for periodicals.

We believe that, even at an increased expense, provided the funds were available, it would be of distinct advantage to the society to publish its own journal, but we are convinced that there will be an actual saving rather than an increased cost. We accordingly recommend that steps be taken to withdraw from the Association of Engineering Societies at the end of the present calendar year, and that thereafter the papers presented to the society be published in an independent journal.

Respectfully submitted,

WILLIAM S. JOHNSON,
CHARLES W. SHERMAN,
S. EVERETT TINKHAM,
Committee.

Mr. Gow moved, and it was duly seconded, that the Secretary be instructed to have prepared and mailed to each member of the Society, on or before June 1, a copy of the Special Committee's Report to the Board of Government, together with a letter ballot on the acceptance or rejection of the recommendations therein contained, said letter ballot to be canvassed at the June meeting of the Society.

Mr. Bryant thought that the report should be discussed at a meeting of the Society, and moved an amendment to the motion providing for the canvass of the letter ballot at the September meeting. On a vote being taken, the amendment was lost. The original motion was then carried by a unanimous vote.

The Committee (Messrs. William Wheeler and Harrison P. Eddy) appointed to prepare a memoir of our late associate Charles A. Allen, presented its report, and by vote it was accepted and ordered to be printed in the JOURNAL.

Prof. Charles M. Spofford then gave a very interesting talk illustrated by lantern slides, on "The Technology Summer Surveying Camp at East Machias, Maine."

Before declaring the meeting adjourned, the President extended a cordial invitation to the guests present to visit the Society rooms on the floor above and examine the additions which had been made to the Society's quarters. The invitation was apparently accepted by all present and a very pleasant hour was spent in the rooms by members and guests, during which light refreshments were served.

[Adjourned.]

S. E. TINKHAM, *Secretary.*

Nahant, Mass., June 25, 1913. — A regular meeting of the Boston Society of Civil Engineers was held this evening at the Hotel Brenton, Bass Point, Nahant, at 8.45 o'clock; President Frederic H. Fay in the chair; 36 members and visitors present.

By vote the reading of the record of the last meeting was dispensed with, and it was approved as printed in the June *Bulletin.*

The Secretary reported for the Board of Government that it had elected the following to membership in the grade of member:

Messrs. Almon L. Fales (transferred from membership in the Sanitary Section), James Joseph Tobin (transferred from Junior) and W. Quintin Williams.

The Secretary announced the deaths of George A. Nelson, who died June 3, 1913, and Past President George Blinn Francis, who died June 9, 1913.

By vote the President was requested to appoint committees to prepare memoirs. He has appointed as the committee to prepare a memoir of Mr. George A. Nelson, Messrs. Richard A. Hale and George Bowers, and as the committee to prepare a memoir of Past President George B. Francis, Messrs. John W. Ellis and Edwin J. Beugler.

The President stated that he had appointed as tellers to canvass the letter ballot on the withdrawal of the Society from the Association of Engineering Societies, Messrs. Edward W. Howe and John N. Ferguson. Mr. Howe reported that 430 ballots had been received, of which 46 had been recalled, leaving 384 ballots counted. Of these, 226 had voted "yes" and 158 had voted "no" on the recommendation of the Board of Government "that the Boston Society of Civil Engineers withdraw from the Association of Engineering Societies at the end of the present calendar year, and that thereafter the papers presented to the Society be published in an independent journal."

Prof. Charles B. Breed then gave a very interesting talk on the "History and Progress of the Elimination of Grade Crossings at Lynn, Mass.," which was illustrated by a large number of lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section Excursion around Boston Harbor.

Boston, Mass., June 6, 1913. — The annual excursion of the Sanitary Section, Boston Society of Civil Engineers, was held to-day. Members and guests to the number of more than seventy gathered at the Quincy, Mass., railroad station at 11.45 o'clock, and were conveyed in a special electric car, furnished through the courtesy of Mr. Ezekiel C. Sargent, to Noterman's Pavilion, Hough's Neck, where a most excellent shore dinner was served. There were 72 members and guests, including a number of ladies, present at the dinner. The Quincy Yacht Club very courteously opened their house to the use of the excursion party, and although the time allowed was very brief. a large number availed themselves of the opportunity to inspect the Club's quarters.

The steamer *Griswold*, of the Nahant line, was waiting at the Hough's Neck wharf to take the party to Nut Island, where opportunity was afforded to inspect the screen house of the South Metroplitan Sewerage System.

Pamphlets were provided by the Society, giving a map of the harbor with the three principal sewer outfalls, the low and high-level intercepting sewers of

the Metropolitan System and the trunk line of the Boston Main Drainage Works.

From Nut Island the party went to Moon Island, to visit the storage reservoirs and appurtenances connected with the outfall works of the Boston Main Drainage System. The sewage had been held later than usual so that the party might see the discharge and its effect on the harbor water.

Messrs. Julius W. Bugbee, Arthur L. Gammage and Dr. Frederick Bonnet, Jr., gave demonstrations of the methods of sampling water at various depths and of analyzing the same for "dissolved oxygen" by both the Winkler and the Levy methods.

The trip from Moon Island to Deer Island was made by a roundabout way in order to observe the sewage discharging from the Nut Island outlet off Peddock's Island and the outlet near Deer Island light.

At Deer Island, the pumping engines, boilers, screens and accessories to the outfall works of the North Metropolitan System were viewed with considerable interest.

It was the intention, after leaving Deer Island, to go to the Calf Pasture Pumping Station in Dorchester, but owing to the stage of the tide and the inability of the steamer to turn in the channel, this part of the excursion had to be abandoned, and instead the steamer sailed along the waterfront, by the new Commonwealth docks and the East Boston docks. The steamer returned to Otis Wharf, Atlantic Avenue, about 5.30 P.M. There were 77 members and guests on the steamer trip.

FRANK A. MARSTON, *Clerk.*

Technical Society of the Pacific Coast.

REGULAR meeting held on Friday evening, July 18, 1913, in the Board room of the Mechanics Institute, 57 Post Street, at San Francisco.

The meeting was called to order at 8.30 o'clock by President Wright.

The minutes of the last regular meeting of June 20 were read and approved.

Mr. B. C. Van Emon read a paper entitled, "Elevators, Their Uses and Abuses," which was discussed at length by those present.

The President expressed the appreciation of the Society to Mr. Van Emon for this very valuable contribution to engineering literature.

Mr. Wright announced the death of Mr. Frank P. Medina, who has been a member of long standing, and also a director of the Society for several terms, and he appointed a committee, consisting of Messrs. A. Lietz and Otto von Geldern, to write a suitable memorial and obituary in honor of the late member.

Mr. W. W. Hanscom, chairman of the Committee on Library Matters, made the following report:

JULY 18, 1913.

Mr. G. ALEXANDER WRIGHT, *President*
Technical Society of the Pacific Coast:

Sir, — Your Committee, appointed to take up the study of what books the Mechanics Library should acquire, from the standpoint of the engineer, to create a first-class technical library in San Francisco for the use of the engineering profession, has the honor to present the following preliminary report for the Society's action.

After a careful consideration of the method which should be pursued in order to make the subject interesting to the engineers in such a way as to obtain individual expressions of opinion as well as the advice from the greatest number, it was decided to suggest that a circular letter be sent to each of the members of local engineering societies, through their respective secretaries, asking for lists of books or publications which, in their judgment, would be most desirable to have for ready reference.

The circular letter would be got up in such form as to leave space for the filling out of the list, which could be returned to the library committee, which would then compile a general list for submittal to the Mechanics Library trustees for their action.

The suggested form of circular letter is herewith included for the purpose of obtaining an expression from the members of the Society, and a tentative list of the Societies whose members would be addressed on the subject is also appended.

Circular Letter.

The Technical Society of the Pacific Coast has been requested by the Mechanics Library to aid the librarian in the preparation of a list of books, periodicals, magazines and publications to be used in the formation of a complete engineering reference library, and thus, in time, fill a long-felt want among the engineering professions of San Francisco and the Bay cities.

To that end, the President of the Technical Society has appointed a committee to formulate a plan by which the wishes of all the members of the various engineering societies, having local branches, could be obtained, compiled and submitted to the trustees of the Mechanics Library for their information and guidance.

The committee thinks the best way of arriving at the desired results would be to have the secretaries of the local branches include in their notices to members a circular letter setting forth the above information and asking each member to submit, at the earliest possible date, a list of all the publications which he thinks would be desirable from his own standpoint and from the standpoint of those of his friends or associates who may not be members of any of the local engineering society branches.

It is contemplated to obtain or compile a complete index system by means of which all the articles relating to a particular branch or subject can be easily found with the expenditure of a minimum amount of time and effort.

As a library of this character will be of great value to the engineering profession, the coöperation of all interested is urgently desired and requested in order to make it as complete and universal as possible.

Copies of the blank forms, for filling out with the above lists, will be furnished upon receipt of the number required.

Respectfully submitted,

W. W. Hanscom, *Chairman.*

It was ordered that the Secretary take up this matter and send out a circular letter as recommended by Mr. Hanscom.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Regular meeting held on Friday evening, August 15, 1913. It was called to order at 8 o'clock in the Board room of the Mechanics Institute, 57 Post Street, by the President, Mr. G. Alexander Wright.

The minutes of the last regular meeting were read and approved.

The Secretary called attention to the fact that this Friday evening, as well as all the third Friday evenings of February, April, June, August, October and December, conflict with the meetings of the Local Association of the members of the American Society of Civil Engineers, and that the meetings of the Technical Society should be changed to avoid the conflict. There are

members of this Society who are also members of the American Society, and who are necessarily deprived of either the one meeting or the other. The lack of attendance is more or less due to this conflict of meetings.

Mr. Wright stated that this matter would be taken up and satisfactorily disposed of at the next meeting of the Directors.

Mr. W. W. Hanscom read a paper entitled, "Progress of Wireless Telegraphy," which was discussed at length by those present.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Louisiana Society of Engineering.

The American Society of Civil Engineers will meet in New Orleans on October 15, 16, 17, 18. The Louisiana Engineering Society and local members of the Am. Soc. C. E. have joined forces in planning the reception and entertainment of the many members who are expected to be in New Orleans on the above occasion.

James M. Robert, *Secretary.*

Utah Society of Engineers.

June Meeting. — In place of the regular Friday-night meeting, the members of the Utah Society of Engineers and their ladies joined in an excursion to the "Hermitage," in Ogden Canyon, on Saturday, June 21, 1913.

Through the courtesy of Mr. Simon Bamberger, of the Salt Lake & Ogden Railway Company, the Society was given a liberal number of free tickets over that route, which contributed greatly to the success of the excursion.

Meeting called to order in the parlors at 4.00 P.M. by President Peters; 45 persons present.

Minutes of the previous meeting read and approved.

The application of Norbert Cecil Manley and Sylvester Quayle Cannon, both of Salt Lake, for membership in the Society, were balloted on and unanimously accepted.

No further business before the Society, the President introduced Mr. Chas. P. Kahler, electrical engineer for the Oregon Short Line Railroad Company, who delivered a very interesting paper on "Steam Railroad Electrification," following which the various points were discussed by Messrs. Harris, Arentz, Cheever, Peters, Brown, Ambler and others.

By unanimous vote, the Secretary was instructed to express to Mr. Simon Bamberger, president of the Salt Lake & Ogden Railway Company, the Society's appreciation of his furnishing transportation over his line from Salt Lake to Ogden and return.

A vote of thanks was extended to Mr. Kahler for his paper.

The Secretary was also instructed to express to Mr. L. M. Bailey and his assistants, Mr. O. C. Hart and Mr. S. M. Seddon, the Society's appreciation of the opportunity to visit the Portland Cement Company's plant on

Saturday afternoon, May 17, 1913, and the interesting manner in which the different features of the process were explained.

Adjourned.

Following the meeting, a pleasant hour was spent on the porches, visiting with the ladies and friends, after which all adjourned to the dining-room, where a fine chicken and trout dinner was enjoyed by the sixty persons present.

On account of train connections, the party left the "Hermitage" at 8.20 P.M.

This our first "Ladies' Day" was a pronounced success, and the ladies have asked that we make it at least an annual event.

FRED D. ULMER, *Secretary.*

Association of Engineering Societies

Vol. LI. | OCTOBER, 1913. | No. 4.

PROCEEDINGS.

Montana Society of Engineers.

Butte, Mont., May 10, 1913.— The meeting was called to order by Vice-President Reno H. Sales. Members present, Messrs. Bard, Sales, Packard, Simons, Goodale, Ingalsbe, Bowman, McArthur, Moore. Minutes of the last annual meeting approved without change. Messrs. M. E. Buck, F. E. Buck, Cunningham, Johns, McLeod, McGee, Mitchell, Munroe and Williams were elected members of the Society. The amendment to Section 1, Article 3, of the By-Laws, changing the date of the regular meetings from the second Saturday of each month to the second Monday of each month, except annual meeting, was adopted. The resignation of Mr. Walter E. F. Bradley was presented and accepted. The Trustees were instructed to procure a lamp for the Secretary. The use of the Society's Room was tendered the American Institute of Mining Engineers during the time of said Society's visit to Butte, August 18, 19, 20. Professor Bard gave a talk on the astronomical relation of the sun and other heavenly bodies. The program for the September meeting was assigned to Professor Bard. Adjournment followed.

Clinton H. Moore, *Secretary.*

Association of Engineering Societies

Vol. LI. | NOVEMBER, 1913. | No. 5.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., September 17, 1913. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, at eight o'clock, President Frederic H. Fay in the chair; 75 members and visitors present.

By vote the reading of the record of the June meeting was dispensed with and it was approved as printed in the September *Bulletin.*

The Secretary reported for the Board of Government that it had elected Charles William Eaton a member of the Society.

He also reported that, at a meeting of the Board held July 7, 1913, a communication was received from his honor the mayor of Boston, requesting the Society to name a person who shall become a candidate for appointment to the Boston Board of Appeal, as provided under Chapter 550 of the Acts of 1907. As the appointment was required to be made before August 1, 1913, the Board acted on the matter and named Mr. Joseph R. Worcester as the Society's candidate.

The Secretary announced the death of Edward A. Haskell, a member of the Society, which occurred on August 24, 1913, and by vote the President was requested to appoint a committee to prepare a memoir. He has appointed as that committee Messrs. Luis G. Morphy and John B. Russell.

Mr. Leonard C. Wason then read the paper of the evening, entitled "The Problems of a Contractor." The paper was discussed by Messrs. A. W. Parker, C. T. Fernald, S. E. Thompson and E. S. Larned.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston, October 15, 1913. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, at eight o'clock, President Frederic H. Fay in the chair; 75 members and visitors present.

By vote the reading of the record of the last meeting was dispensed with, and it was approved as printed in the October *Bulletin.*

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Chester Arthur Moore, Carl Stuetzel, Jr., William Leuty Vennard and Francis S. Wells.

Junior — Harry P. Burden.

The Secretary read a communication from the Mississippi River Levee Association, asking this Society to take some action approving the plans of the Mississippi River Commission and recommending favorable action by Congress for carrying out these plans.

On motion of Mr. Weston it was voted to appoint a committee, consisting of the President and two members to be named by him, to consider the matter of the communication, and, if they deem it advisable for the Society to take action in the matter, to report their recommendation in print in the next issue of the *Bulletin*. The President has named as his associates on the committee Messrs. Frank W. Hodgdon and Frank A. Barbour.

A communication was also received from the secretary of the National Conservation Congress, inviting this Society to appoint three delegates, with alternates, to represent the Society at the Fifth National Conservation Congress, to be held in Washington, D. C., November 18, 19 and 20. By vote the President was authorized to appoint the delegates, if he can find members available for the purpose.

Mr. John L. Howard then read the paper of the evening, giving an account of the work of the directors of the Port of Boston. The paper was illustrated with lantern slides.

Past President Frank W. Hodgdon gave some additional facts of interest relating to the work of the directors.

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

Boston, Mass., October 1, 1913. — The regular October meeting of the Sanitary Section, held to-day, was conducted in the form of an excursion to the Calf Pasture Pumping Station of the Boston main drainage system in Dorchester. The meeting was opened at two o'clock P.M. by the chairman. There was no business transacted.

Mr. Edgar S. Dorr, chief engineer of the Sewer Service, Department of Public Works, assisted by Mr. Sanborn, guided the party through the screen house, boiler room, incinerator room and pump room, where all parts of the plant were fully described and discussed. The twin units of steam turbine driven centrifugal pumps now being installed were the center of much interest, especially on account of their very low initial cost compared with the high duty Leavitt pumps. The discharge channel between the pumps and the tunnel under Dorchester Bay was also examined.

Mr. Dorr gave a very interesting description of his experiments on the chemical precipitation of sewage discharged by the pumps. The experiments were made in two small tanks of a capacity of approximately 1 300 gal. each. The sewage before entering the tanks is treated with sulphur dioxide gas, forming a precipitate which settles out in the tanks. From the precipitate thus formed, Mr. Dorr hopes to be able to obtain a sufficient amount of grease and material of value as a fertilizer to cover the cost of operation of the chemical precipitation plant, and at the same time accomplish a partial purifica-

tion of the raw sewage. The method of applying the chemicals was illustrated by the chemist, Mr. Miles.

There were 25 members and friends present.

FRANK A. MARSTON, *Clerk.*

Montana Society of Engineers.

BUTTE, MONT., SEPTEMBER 8, 1913. — The regular meeting of the Society was held at the usual hour, with Vice-President Sales in the chair. Members present: Messrs. Bard, Packard, McArthur, Sales, Moore, D. G. Donahoe, Kemper, F. T. Donahoe; two visitors. Minutes of last meeting approved. The application for membership in the Society of Carl B. Lockhart was read and the regular ballot ordered. The President's and Secretary's acts in naming Delegates Carroll, McMahon, Swearingen, Gerry, Brown and Covell to the Good Roads Convention at Kalispell were approved by vote of the Society. The Secretary was instructed to purchase a suitable lamp for desk use. The Vice-President appointed Messrs. Davis, Haven and Mathewson delegates to the American Road Congress to be held at Detroit, Mich., September 29 to October 4, 1913. Mr. Geo. A. Packard gave a very interesting talk concerning the Cook City mining district, discussing its various geological features, ore developments and pressing need of railroad communication. Maps and pictures and expressions of other members added to the talk in the way of increased interest.

Adjournment.

CLINTON H. MOORE, *Secretary.*

BUTTE, MONT., OCTOBER 13, 1913. — The October meeting of the Society was held at the usual place, with Vice-President Sales in the chair. Present: Messrs. Sales, Dunshee, Carroll, Bard, Simons, Moore, F. T. Donahoe, Packard, Whyte, Kemper, Barker, Goodale. Minutes of the last meeting approved. Carl Brown Lockhart was elected to membership by a unanimous vote. The chair appointed C. H. Bowman, F. R. Ingalsbe, Frank D. Jones as delegates to the Fifth National Conservation Congress, which meets in Washington, D. C., November 18, 19, 20, 1913. The question of the withdrawal of the Society from the Association of Engineering Societies caused a general discussion and resulted in the appointment of a committee who should give the subject careful investigation and report their findings at the next meeting of the society. The committee appointed are, Barker, Moore, Dunshee. By vote the sense of the members present was expressed that there should be no withdrawal, provided the expense of the JOURNAL remained about as present. Sam'l Barker, Jr., member of the Board of Managers of the Association of Engineering Societies, was instructed to vote for Messrs. Williams and Peters as President and Secretary of the Association for the coming year. The floods of the Mississippi River and their prevention was chosen as the topic for discussion at the next meeting.

Adjournment.

CLINTON H. MOORE, *Secretary.*

Technical Society of the Pacific Coast.

Regular meeting, held on Friday evening, September 19, 1913, in the auditorium of the Young Men's Christian Association, 220 Golden Gate Avenue, San Francisco.

The meeting was called to order at 8.30 o'clock by President Wright.

The reading of the minutes of the last regular meeting was dispensed with.

Mr. Robert Newton Lynch, manager of the California Development Board, addressed the Society on the subject of the "Development of the State of California," pointing out the great future of the country and the methods of its rational development.

This subject was discussed at length by those present.

The meeting adjourned.

Otto von Geldern, *Secretary.*

Regular Meeting, October 30, 1913, called to order in the Board Room of the Mechanics Institute, 57 Post Street, San Francisco, at 8.30 o'clock p.m., by President Wright. The minutes of the last regular meeting were read and approved.

Mr. D. F. Leary read an interesting paper on the subject of "Protective Paints and Pigments," which was discussed at length by those present.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Utah Society of Engineers.

Salt Lake City, Utah. — The regular meeting of the Society was held in the "Call Room" of the Salt Lake Stock-Mining Exchange at 8.00 p.m., Friday, September 19, 1913. About 50 persons present.

The minutes of the June meeting were read and approved.

Mr. Wilson, chairman of the Program Committee, reported that arrangements had been made for papers as follows:

October: "Electrical Transmission in Utah."

November: "Water Supply and Distribution in Salt Lake."

December: "Road Making: Highways in Utah."

In addition, the following subjects were being considered for future meetings:

"Gas Manufacture," "Valuation of Public Service Properties," "Telephone Construction" and "Refrigeration."

An invitation to participate in the proceedings of the International Engineering Congress, to be held in San Francisco in 1915, was read.

The applications of Oliver J. Egleston, assistant consulting engineer, United States Smelting, Refining and Mining Company, and Charles S. Vadner, chemist, 2505 South 9th East Street, both of Salt Lake City, were balloted on and they were accepted as resident members of the Society.

Following the business meeting of the Society, Dr. A. H. Thiessen, director of the United States Weather Bureau at Salt Lake City, read a very interesting paper on the subject: "Data on the Atmospheric Condition in the

Salt Lake Valley," after which Mr. O. W. Ott, consulting engineer, read a paper entitled "Possibilities of Reducing the Smoke Production in Salt Lake City."

Both of these papers were illustrated with lantern slides and photographs.

Following the reading of the papers a lively discussion of various points was participated in by Messrs. Beckstrand, Ott, Kahler, Tibby, Brown, Overfield and others.

Adjourned.

FRED D. ULMER, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES

VOL. LI. **DECEMBER, 1913.** No. 6.

PROCEEDINGS.

Louisiana Engineering Society.

REGULAR MEETING OF THE SOCIETY, OCTOBER 13, 1913. — The meeting was called to order in Gibson Hall, Tulane University, President Shaw presiding.

The report of the Committee on the Resolutions for Mr. Haugh was received. This report forms a separate page in these minutes.

The technical exercises of the evening were then held. Mr. A. L. Webre, member of the Society, read a very entertaining and instructive paper entitled, "Recent Developments in Evaporation." After some little discussion by several members, Mr. Webre was tendered a rising vote of thanks.

Announcement was made of the program of entertainments for the coming meeting of the American Society of Civil Engineers.

A communication from the Mississippi River Levee Association was read, but no action was taken thereon.

There being no further business to come before the meeting, the same was adjourned.

JAMES M. ROBERT, *Secretary.*

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